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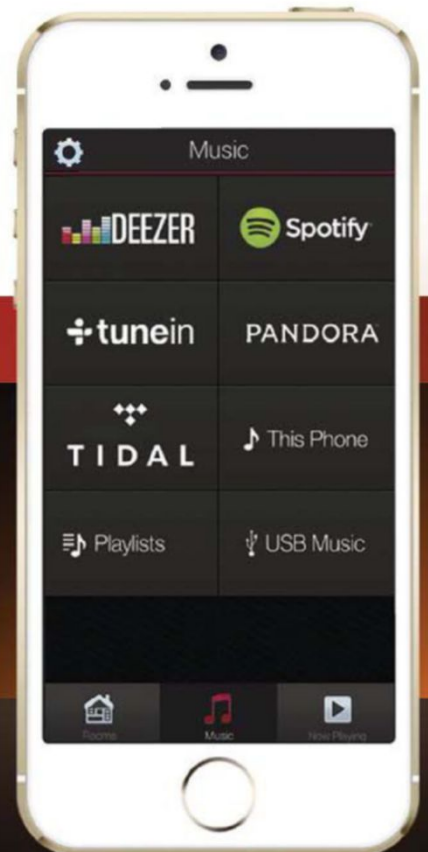
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A Bit About Us

Bounce Imaging Rolls Out

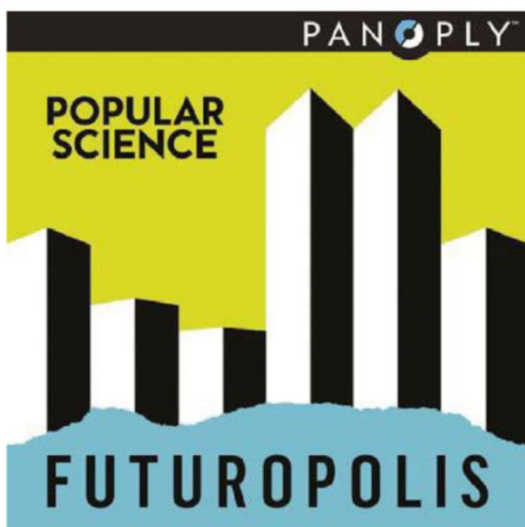
In 2013, we gave an Invention Award to the Bounce Imaging Explorer. The rugged ball holds a panoramic camera that police can toss into potentially dangerous sites before entering. After testing 20 different models, Bounce Imaging released its first product to police departments this past July.



SECRET EXPERTISE

Clearly, we know how to put a magazine together, but it turns out some of us have a few other skills up our sleeves. An abridged list:

- Licensed massage therapist
- Professional clown
- Outdoor guide
- Figure-skating instructor
- Fermentation enthusiast
- Astronomer



LISTEN UP

Ever wonder what it'll be like to walk your dog, commute to work, or eat dinner—in the future? Us too. This summer we launched our podcast *Futuropolis* to find out. Listen at soundcloud.com/popular-science.

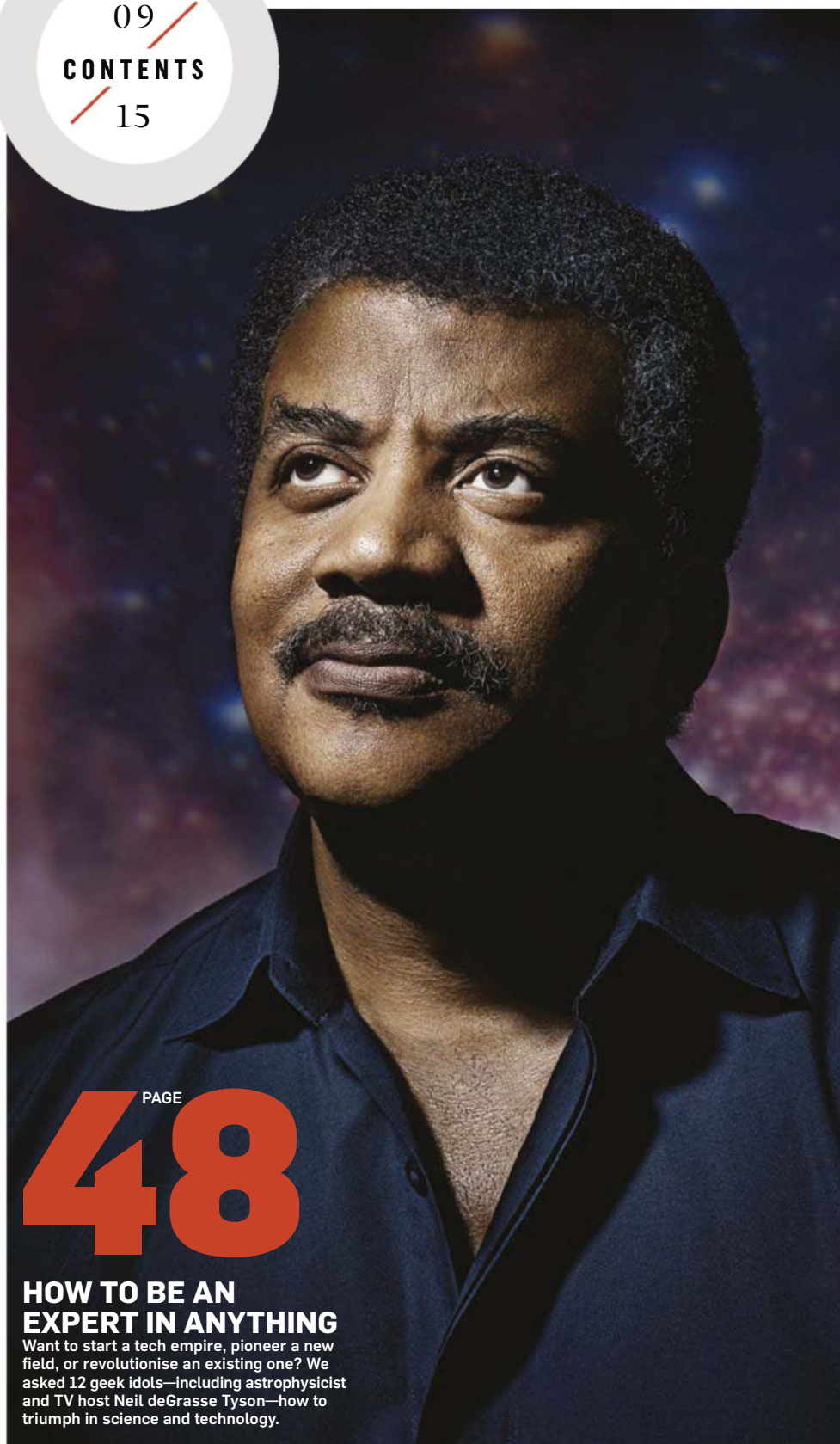


ROBOT HELPER GETS HIRED

For our November 2014 issue, we sent a writer to Japan to meet the first wave of social robots. This June, Japanese telecom Softbank began selling Pepper, one of the robots we featured. The first 1,000 units sold out in one minute.



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HOW TO BE AN EXPERT IN ANYTHING

Want to start a tech empire, pioneer a new field, or revolutionise an existing one? We asked 12 geek idols—including astrophysicist and TV host Neil deGrasse Tyson—how to triumph in science and technology.

Featuring

EUROPA OR BUST

Jupiter's moon might hold the life we've long searched for in space. Scientists have one shot to reach it. **COREY S. POWELL**
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UBER POWERFUL

The car-service company has a brazen plan to dominate robotics. Should we be excited or afraid? **ERIK SOFGE**
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GO HACK YOURSELF

Tired of the body you have? Consider a few aftermarket options. **BOB PARKS**
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THE LESS-NOBLE NOBELS

The annual tribute to science's funniest research celebrates 25 years. **KATIE PEEK**
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ON THE COVER

The proposed Juno probe could be part of a new mission to discover life on Europa

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Thirty years: It's shorter than you think

One of the constant criticisms of any technology that claims it can change the world - energy, communications, IT, medicine, whatever - is that it's "30 years away". Conservative politicians in particular seem to constantly rail against investing in research because returns are "30 years away".

It's an odd choice, that 30 years. If you're anti-technology, why not say 50 years? At least you're claiming the thing won't benefit anyone in your constituency except the very young.

But 30 years now, that's exactly the span that should make first-time voters sit up and listen. You tell an 18 year-old that something is 30 years away, and they can look forward to it directly benefiting them in the prime of their life.

Think of the first batch of Tesla owners. These guys grew up in the 1980s being told that cars would be fully electric and massively fast with cool touch screen controls "in 30 years". And here we are, just in time for those long-ago kids to have built themselves a life where dropping \$150K on a version 1.0 electric sedan is something they can actually do.

Medicine is another area where "30 years from now" is a constant mantra. Thirty years ago, diabetes patients had to find a quiet place to inject

insulin, perhaps even with a reusable glass syringe. Today, diabetics can volunteer to trial automated insulin pumps and blood glucose monitors that have smartphone apps. Thirty years from NOW? Artificial pancreas.

Thirty years ago, critics said home solar power was at least 30 years away. Thirty years ago, we dreamed of having pocket-sized personal computers capable of wireless communication.

Thirty years ago, I was eight years old. I watched Beyond 2000 religiously. I looked forward to a future that has now arrived.

And perhaps, certainly among people under 50, the old "30 years" mantra is falling out of favour. We live in a wild and baffling future already, and we know that in most cases, predictions of where technology would be in 2015 were way too conservative. So we're more cautious. Thirty years from now is the year 2045.

We're told the 2040s will be the era of the Singularity, of functional immortality, of uploading personalities to computers. So if the trend of understating the possible continues, 2045 will be even wilder than we think.

There is one important piece of technology that seems to be bucking the 30 year rule: fusion power. But just because we don't have a reactor outside every major city, don't think there hasn't been massive effort and innovation poured into fusion. It's just that, unlike so much that has gone before it, fusion is HARD. We're talking about building a tiny star on Earth, and sucking power out of it. It's a slightly bigger job than the invention of the iPhone.

The point I'm making here is that the kinds of people who scoff and say "pfft, that's 30 years away" are stuck in an old, disappeared world where adults lived to their mid-50s if they were lucky. Today's teens will almost definitely live into their 110s. Time is very much on their side.

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POPULAR SCIENCE

Issue #82, September 2015

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Popular Science is published 12 times a year by nextmedia Pty Ltd. ACN: 128 805 970
Building A, 207 Pacific Highway
St Leonards, NSW 2065

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RETRO-FITTED

I'd love to see more of Iavis Coburn's artwork [July 2015] inside the pages of *Pop Sci*. The bright colours and vintage texture seemed like a throwback to the optimism of the old days, when it was inevitable that science could solve everything. It got my heart pounding!

BJ Hill

A BETTER COMMUTE

Instead of the hyperloop ["Hyped Up," July 2015], a better/faster/cheaper transportation method would be a highway for driverless cars. Rarely mentioned in high-speed-transportation discussions is the time it takes to get to the terminal and make it through security. Is there anyone who doesn't want to go 250 km/h on a driverless highway? The only thing missing is a fancy name!

Jeff Kotowski

ETHICS OF COMBAT

I loved the article "The Future of War" [July 2015] except for one item: The idea that every military strike fighter will be automated is not something I think should happen. A robot will never make judgment calls about a target that has women and children lined up as a human shield. It is far too easy to never have to live with the decisions made.

Bradley Harden

TWEET OUT OF CONTEXT

Of course that's what the "robot expert" says. They have him in their thrall. @theurbansherpa



BITING BACK

In July we covered the spread of dengue fever, which infects 400 million people worldwide, and the mosquitoes that have been genetically engineered to curb it ["Mosquitoes Designed to Self-Destruct"]. We posted the story on Facebook and readers responded. The insects should be happy to learn they have some defenders:

Christopher Drysdale Mosquitoes serve a purpose or they wouldn't be in that niche ecologically. Guess we'll find out what it was.

Dave Baker They got rid of snakes in part of India and were soon overrun with rats!

Rich Myers What could possibly go wrong... asked the guy who crossed honeybees with African bees.

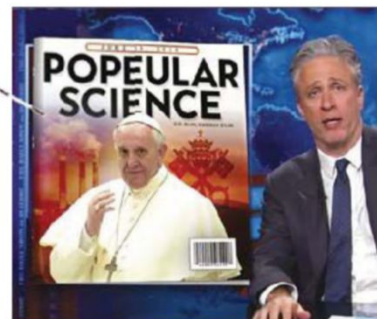


HAVE A COMMENT?

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AN INCONVENIENT CANON

On June 25, Jon Stewart, host of *The Daily Show*, used a play on the cover of *Popular Science* to illustrate Pope Francis' encyclical on climate change. To read about the Pope's recent stance, turn to page 16.



CELESTIAL PAIR

Reader Babak Tafreshi captured this image of Jupiter and Venus during their conjunction over Boston the night of June 30--an event he called "quite a sight."



Life on Ice

On page 36, we describe NASA's future mission to Jupiter's moon Europa. What life-form do you hope we'll find under its icy surface? Tweet your answer to @popsciau #europanlife.



Parrot minidrones



NEW GENERATION LANDING
IN STORES SEPTEMBER 2015



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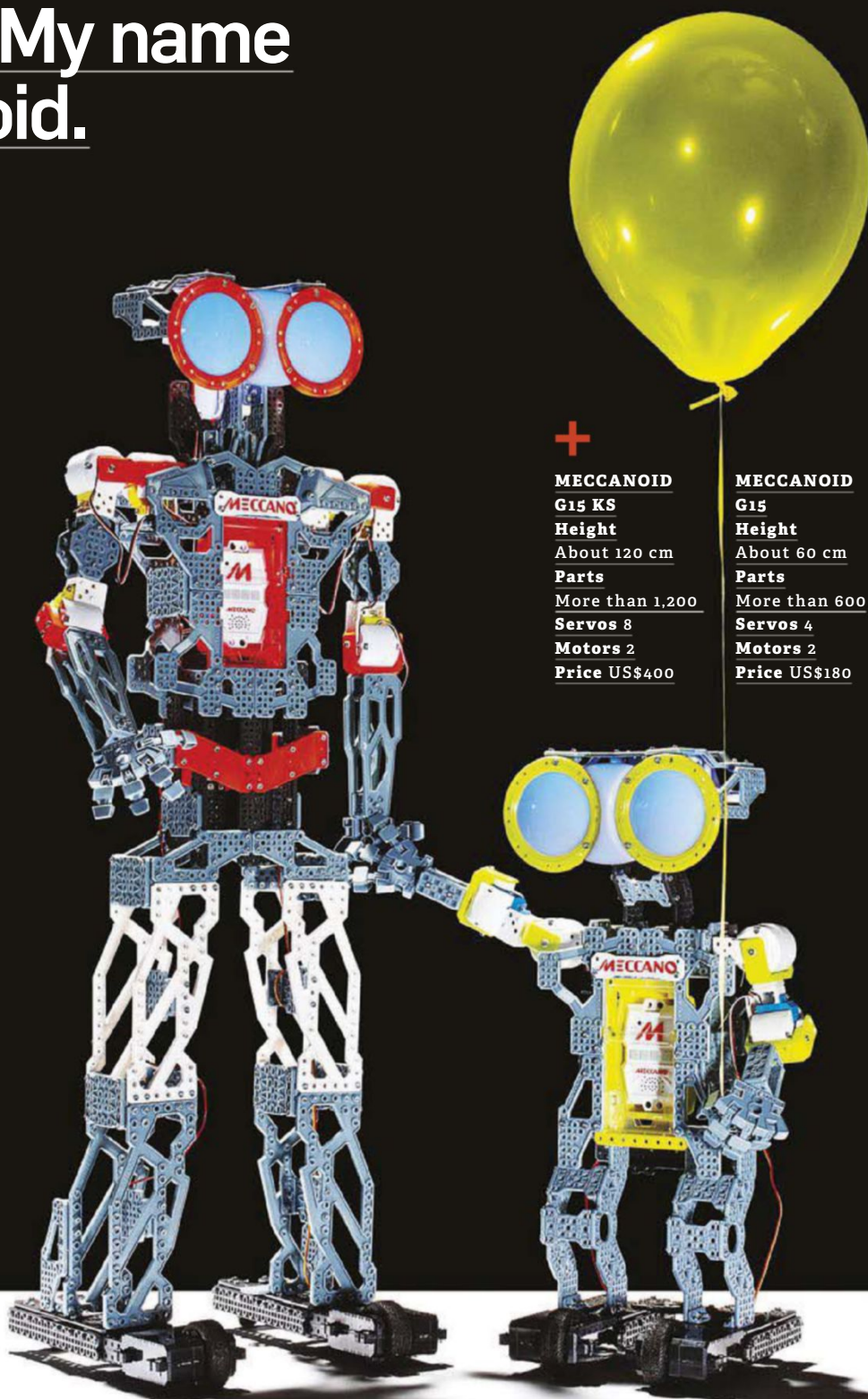
Greetings! My name is Meccanoid.



Tinker Toys. LEGO. Lincoln Logs. They're all great. But none evoke the essence of construction quite like the snap-it, screw-it, city-building brilliance of the Erector set, which has inspired tiny tinkerers for more than a century. The latest kit from parent company Meccano is the Meccanoid—the smartest DIY bot to ever spill out of a box. The kit contains hundreds of parts that you can reassemble into countless forms—from scorpions and spiders and kid-size raptors to these almost lovable humanoids.

Once assembled, Meccanoid can crack jokes, act on voice command, and be programmed with custom moves. You can do this in three ways. First, the robot can learn movements as you adjust its arms and head, just like you would with a puppet. Second, when paired with an app, you can control Meccanoid using a drag-and-drop skeletal avatar on a smartphone. Third, you can put a phone in Meccanoid's chest cradle. The robot can then use the phone's selfie cam, along with an app, to mirror your gestures.

Unlike heavy-metal Erector sets, Meccano's parts are made of plastic. The reduced weight (and lack of sharp edges) means it's not going to hurt anyone if it tips over. And although the parts might look a lot different than the metal ones that premiered in 1913, these kits are made with the same original intention: to light up the imagination and get you building. **MICHAEL NUÑEZ**



MECCANOID

G15 KS

Height

About 120 cm

Parts

More than 1,200

Servos 8

Motors 2

Price US\$400

MECCANOID

G15

Height

About 60 cm

Parts

More than 600

Servos 4

Motors 2

Price US\$180

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Obsessed

Some things are just...better

LINDSEY KRATOCHWILL

(Prices are shown in US dollars... because why stop hating ourselves just when its starting to get fun?)

1 TOSHIBA SATELLITE RADIUS 15

This laptop-tablet hybrid is the first of its kind. With a 4K screen, you can edit your ultra-high-definition footage and then flip the screen to show off your dazzling creation. **\$1,200**

2 HYDROFOIL DRONE

Parrot's Rolling Spider drone is pretty fantastic, but it's not made for water. The company has fixed that shortfall with the Hydrofoil. The flying drone can now attach to a pair of skids that can glide across water at speeds of about 10 km/h. **\$179**

3 TORQUE T402V

Can't decide what kind of headphones to buy? Torque makes it easy. With a quick adjustment, users can pop off the ear pad and turn it to change the amount of bass to their liking. **\$400**

4 VARIA SMART BIKE LIGHTS

Thanks to GPS data, Garmin's new lights know when you're blasting ahead at high speeds or creeping along in traffic. The beam automatically projects farther at faster speeds so you can see obstacles ahead. **\$300**

5 SUPER MARIO MAKER

It's been 30 years since the mustachioed plumber started hopping around screens. To celebrate, Nintendo's new Wii U game lets you design your own levels. And if that's too much work, you can try

ones designed by other players too. **\$60**

6 WORX AIR WITH TURBINE

Blowing damp leaves off the lawn requires big blasts of air. Worx redesigned its cordless blower so the airflow intake moves air straight through the nozzle without the usual baffling. If you don't need all that power, you can switch outputs to handle lighter jobs. **From \$99**

7 PIXIE TRACKER

Don't know where the keys ran off to? GPS trackers don't work well indoors, and Bluetooth signals offer only proximities. So the Pixie trackers use mesh networks to connect to each other to give more-accurate locations. **\$70 for four**

8 IBM CHEF WATSON

The brain that beat Ken Jennings in *Jeopardy* can now help you make dinner. The Watson Web app, formerly in beta, is now available to anyone. Type in a few ingredients to see what quirky recipe combinations Watson cooks up. **Free**

9 CHILLED

The hulking fridge might not seem like cutting-edge tech. But in his new book, Tom Jackson describes how the ability to cool things down has changed history. And since refrigeration has helped discover superconductors and enable in vitro fertilisation, it's likely to change the future, too. **\$27**

10 ANKI OVERDRIVE

Robotic toy cars are already cool; Anki has made them cooler. Players can now pit toy supercars against friends (or nemeses) and against the AI commander on their own customisable racetracks, thanks to modular, magnetic pieces. **\$150**



SOMETHING
BIG
IS COMING

20 AUGUST 2015
11 PM

#HOME OF SOUND



The Future Arrives by Sedan

When the **BMW i8** rolled off dealer lots this past year (see p22), the few gearheads who could afford one were awed: Zero to 100 in 4.2 seconds, a carbon-fibre body, and a slate of futuristic features, including a no-blind-spot panoramic view of the road, made this three-cylinder hybrid a list-topper in several categories.

Now BMW is pouring the i8's feature set into its more classic and affordable models. The 2016 7-Series is the first. To start: its carbon-composite body gives this luxobarge surprising athleticism, as it weighs 130 kg less than its predecessor.

The 7-Series also packs in a few

2016 BMW 730e

0-60 speed

5.6 seconds

Engine

240 kW

Fuel economy

2.1L/100km

Price \$TBA

innovations of its own. It's the first car in the world to offer gesture control, allowing drivers to direct the infotainment system like an orchestral conductor. A camera watches for hand movements. With various midair swipes and swoops, drivers can adjust stereo volume, answer phone calls, or activate navigation to preset destinations.

The interior is made of carbon-fibre reinforced plastic to make the car lighter and stiffer. This improves the car's handling and reduces its total weight by 85 kgs, which increases fuel economy. The plug-in hybrid model goes even further with a 2-litre petrol engine, and an electric motor in the transmission. In electric driving mode, the 7-Series has a 37-kilometre range and a top speed of 120 km/h.

To boost interior atmospherics, BMW etched hundreds of tiny dots in the panoramic moon roof, all lit by a perimeter of LED lights. The result: a calming field of stars floating overhead, even on the cloudiest of nights. The whole car could leave many similarly star-struck. **ERIC ADAMS**



DESIGN OF THE MONTH

SRT Tomahawk X

With 1,865 kW, a top speed of 640 km/h, and a partially pneumatic drivetrain, the SRT Tomahawk X could revolutionise racing. Its design, already optimised for downforce and reduced drag, employs movable aerodynamic panels to adjust its shape on the fly, improving cornering and stability for every stage of driving. The real car is at least 20 years away, but you can drive it today—by downloading a virtual model with PlayStation 3's *Gran Turismo 6*.

"Gesture control allows you to direct the infotainment system like a symphony."





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KRELL
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STAX

PURE
MAPLE

A HEADPHONE GROWS IN BROOKLYN

Audiophiles speak in reverent tones about the Grado family and their headphones—even though Grado Labs, which makes them, hasn't spent a dime on advertising since 1964. The warm and full-bodied sound of Grado's handmade headphones have been enough to keep them consistently stocked in high-end audio boutiques. Sadly, earlier this year the company founder and family patriarch, Joseph Grado, died. The Grado kin have now decided to pay homage to him and their Brooklyn legacy with a limited-run headphone—made from a local maple tree once destined for the wood chipper.

Their new Heritage Series GH1 headphones are carved from a tree that stood near the company's original headquarters in industrial Sunset Park, Brooklyn. "These trees were about to fall down," says 24-year-old great-nephew, Jonathan Grado. "We bought one from the city and made a bunch of headphones."

His father, John Grado (founder Joseph's nephew), has run the company since 1990. He hand-tunes every headphone the family ships.

"What people love is our midrange sound," says John, noting that 80 per cent of all music we listen to lives in that sweet spot. Up until now, the Grados have relied on mahogany, known for bringing beefy mids out of an otherwise balanced sound. The Heritage Series uses maple, which offers bright highs, punchy lows, and a more precise sound overall.

+
GRADO GH1
Price US\$650
Wood Maple
Availability
~1,000 units

To tune his headphones, John uses an intuitive rather than a technical approach. "I never watch the frequency meter," he says. "If I look at a meter, I'll start hearing what it's displaying and not the true sound." But it was Joseph Grado who gave him that golden ear. "My uncle trained me," he says. "He taught me that listening to sound is like looking at a painting. You're not looking at the whole painting. You're looking at the brush strokes, listening to a particular part of a song. You really have to get in there and listen."

MICHAEL NUÑEZ

THREE GENERATIONS OF GRADOS



Joseph Grado
Handcrafted turntable needles.



John Grado
Made the first Grado headphones



Jonathan Grado
Heir to the Grado headphone legacy.

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The Robot Whisperer Upgrades Your Hotel Stay

↓

Soon hotels will be teeming with robots. At least that's the hope at Savioke, a startup that develops robots for the service industry. The company's room-service helpers have made more than 4,000 deliveries so far. Its newest robot, Relay, has been deployed in about 10 early-adopter locations, delighting most guests but committing the occasional faux pas. To find out what it will be like when there's a robot in every hotel, we spoke with Tessa Lau, Savioke's co-founder and chief robot whisperer.

EDITED AND CONDENSED BY
LINDSEY KRATOCHWILL

Popular Science: How exactly does a robot work in a hotel?

Tessa Lau: It's a delivery robot. When the front desk needs to send an item up to a guest room—an amenity like a toothbrush or a towel, or a sandwich or a snack—they go over to the robot, put the item into its compartment, and send it off. Relay knows how to take the elevator and make its way up to the guest's room. When it gets there, it calls the room phone. So the guest comes to the door, Relay opens its compartment, and the guest retrieves the item. We got complaints when the robot just delivered its item and went home. Now it stays a little bit to interact with the guest. It gives people a chance to shoot video or take a selfie with the robot before it heads on home.

PS: Sometimes humans can be creeped out by robots. How do you overcome that?

TL: One design element is the robot's eyes. They blink. They're on its little tablet. That makes the robot look more human, a little cuter—but yet, not fully human. That's one of the balances we have to strike. If it looks too humanlike, people assume it can do things that it can't. We already have people saying “Hi, robot, how are you?” It's hard for a robot to respond to that. So it doesn't. And in a similar vein, it makes little beeping noises rather than talking to you. That's because we don't want you to think it's smarter than it actually is.

PS: What happens when it doesn't respond like a human would?

TL: There was one incident in the Aloft Cupertino hotel where a little girl saw it and got so excited. She went up to it and hugged it, and was dancing all around it. The robot was trying to get past her into the elevator, but she was blocking its path. And at that point, an inebriated man came

“OUR GOAL IS TO CREATE TECHNOLOGY THAT DISAPPEARS INTO THE BACKGROUND, WHICH IS HARD BECAUSE ROBOTS ARE SO SEXY.”

up and got angry, and so he kicked the robot and slammed it into the elevator. It was fine—robots don't get angry. So the robot just found itself in the elevator, turned around and faced the door, and went to the second floor. We build them to withstand enough abuse under daily use.

PS: How does it make you feel watching Relay work?

TL: I wrote a lot of the code behind it, I had my hands on so much of the technology, and I saw it being built. Even so, it's amazing just watching it do its thing. The robots start to take on personalities. You could say it's because they have slightly different motor adjustments underneath.

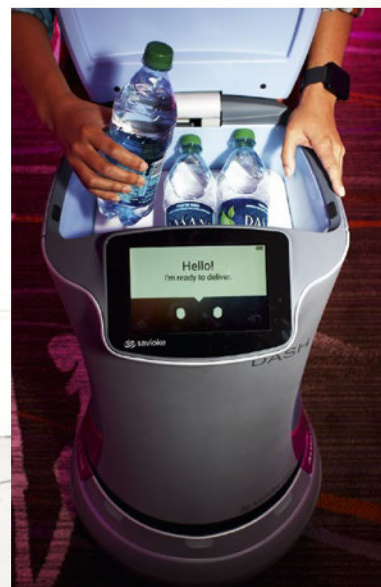


ILLUSTRATION PHOTO BY CREDIT HERE



They're each calibrated a bit differently. Therefore, they have slight variations in performance. They start to take on little quirks. Like, the one guy I was working with yesterday—Beta 6—it's really quiet. It rolls along so smoothly, you can barely hear it coming. And it just peers around the corner. It's still magical watching it go.

PS: Where else do you want to deploy Relay in the future?

TL: There are a lot of places where it could be useful. As a side project, we're looking at robots in elder care, and we've seen interest from places like sports stadiums—to do deliveries to box seats—office buildings, on cruise ships, airports, restaurants, hospitals. They are all indoor spaces where stuff has to move around—and we can help. 📦

Extended Play

Living with the i-Cars



The most extraordinary thing about BMW's eDrive family of electric (or semi electric) cars isn't their outrageous, motor show concept design. It's that the two cars in the "i" lineup are so radically different.

First, there's the i8, a halo car for hybrid if ever there was one: light and nimble and delivering 90% of the Porsche 911 experience with 40% of the fuel consumption. A total package that looks amazing on the outside and somehow familiar in the cabin.

The i3 on the other hand is, in many ways, the more radical of the two. The exterior is polarising. The snub nose gives it city chic but the beltline and scooped-down rear windows make you wonder if someone mixed up the plans a bit. Inside though, the cabin is straight off the set of *Star Trek: The Next Generation* - a late 1990s view of a future three hundred years from now.

Neither car represents what you would call a "value proposition". The i8 is a cramped roadster that costs as much as an M6, while the i3 is a hatchback with the sticker price of a luxury sedan and offers careful drivers a mere 140 km of real-world range.

But of course, these cars aren't for ordinary people. Not even ordinary rich people. The kind of person who seriously considers the i8 is the kind of person for whom the phrase "twin turbo V8" does nothing. They want to know that their 4.2-seconds-to-100 car uses the same engine as a Mini, with just three cylinders and 1.5L of displacement.

And the i3 owner has the cash to buy some kind of pimped out Audi, but they're not looking for screaming hot hatch performance. In an early time they might have picked up a Smart ForTwo to make a statement, but now they can have a similarly declamatory car without worrying about, you know, being crushed to death by a B-double.

In the i-cars, BMW has brought to market two concept vehicles with wild styling, but which remain remarkably easy to live with. The only new habit the owner needs to learn is to plug in every night to ensure a full battery in the morning. Apart from that, both these cars are as easy to jump into and drive down the shops as a VW Golf. **ANTHONY FORDHAM**

PREPARE TO BE PHOTOGRAPHED: LIFE WITH THE I8

My i8 was white. There are other colours, but white was mine. This clean tone set off the car's black elements (various aerodynamic bits and the massive outlet for the cooling fan at the front over the electric engine) and seemed to downplay the sci-fi rear end. Of course, this only made more people want to photograph it.

Sydney is a great town to get tailgated in, and when you're driving a \$300,000 GT that isn't yours, it's never entirely comforting to glance in the rear mirror and see a guy in a Nissan Maxima balancing a cup of coffee on the top of his steering wheel while he films you with an iPhone.

In basic Comfort mode, the i8 drives like a softer, gentler 911. The shove and weight is most definitely behind you, but the all-wheel-drive system is obvious too. Acceleration is smart for the first five metres thanks to eDrive, then drops off a bit, then comes back on as the little three-cylinder burbles into life. Then power just builds and you realise yes: this is a rich person's



GAMING THE SPEEDO: LIFE WITH THE I3

The i3 is harder to fall in love with at first sight. It's a weird little lump but after a few moments of thoughtful contemplation, you begin to learn the design language. This car is space



Extended Play

Despite its looks, the i8 is the more traditional of the pair, at least as a driving experience.



BMW i8
Power: 266kW
Torque: 320 + 250Nm (petrol + electric)
Top speed: 250km/h (120km/h electric only)
Claimed electric range: 37km
Electric range as tested: 21km
Battery capacity: 7kWh
Charge time (80%): 2 hours
Weight: 1485kg
Price: \$299,000

toy that goes stupidly fast.

The upward-opening scissor doors never get old and make you hunch your shoulders as you get in and out - mostly because you can hear people shrieking "look at that CAR!" from down the end of the block.

The cabin is, despite the exterior, oddly conservative. Sure everything is swoopy and asymmetric but all the controls are in familiar BMW places and the gear lever is pretty much the same as the one in an X5.

BMW's M-cars have a drive mode selector with SPORT at the top and

COMFORT at the bottom, but in the i8 it has COMFORT at the top and ECO at the bottom. To get into sport mode, with the angry red dash and all, simply flick the gear lever to the left as if engaging manual shifting mode. Indeed, paddles behind the wheel are now ready to go, but the car will also shift the Japanese-built six-speed transmission itself if you let it.

In sport, the i8 is an animal. Okay, the engine noise might be faked up some, but the combination of a howling three-cylinder and whining electric motor up front is intoxicating

- especially at night where you can configure the interior LEDs to blue, white or orange depending on mood.

What causes fatigue in the i8 isn't the seating position, the relatively thin seats, the boot-camp scramble in and out or even the confusing dials on the dash in Comfort mode. No, it's the attention. That gets old fast. Smiling children are fine of course. But like all supercars, girls aren't interested, and there's always that guy at the service station who comes up to you with a sneer and says: "Is that YOURS?"

pod to the extreme, snub-nosed but sitting tall on hilariously thin tyres (155s all round by default). But those tyres and the lack of an engine under the little bonnet are the first clue to the essential utility of this thing: the turning circle is amazingly tight. We're talking almost London cab tight.

But leave the exterior for "later consideration" and clamber aboard. Obviously, jumping from the i8 into this reaffirms how pleasant it is to get in a car that has been designed for the height of the average human butt. Inside is airy and just plain nice. Its minimalist: the central display floats above a sweep of reclaimed wood, and the materials are finished to evoke a sense of whole foods and multigrain and found art and reframing the moment.



This is the ultimate hipster car, especially because of the irony that no true hipster could afford it.

But someone who designed an app that makes \$20K a month? I can see them leasing this thing on a salary sacrifice, absolutely. The i3 has a small footprint, but inside there's ample space for four adults - the decision to makes it a four-seater keeps the cabin surprisingly spacious.

And there are those who say a car is made or broken on the quality of its "touch points". Every surface in the i3 is beautiful to touch. The rough woollen weave of the seats and window trimmings, the chunky



BMW i3
Power: 125kW
Torque: 250Nm
Top speed: 150km/h
Claimed range: 190km
Range as tested: 120km
Battery capacity: 18.8kWh
Charge time (80%): 8 hours
Weight: 1270kg
Price: \$63,900

"tomorrow's world" tech of the column-mounted shifter.

How does it drive? Who cares - it's fleet enough, though the accelerator feels more like flexing a small muscle than opening a gateway to raw power... The range readout is a constant presence - the Blue Number of Doom. Never really bothered to remember how far it is from work to home in precise kilometres? The i3 will teach you.

It becomes a game. You've travelled 11 km, but the range has only dropped by 7 - you're winning! The car even gives you a star rating on several metrics via the i-app. I got five stars for "anticipation" (using the regenerative braking rather than the brake pedal) but only one star for acceleration - hey, part of my job is to test performance right?

In the i3 you will never be the fastest or indeed zippiest car on the road. But unlike other frugality-mobiles, hills aren't a problem - though you will curse their deleterious effect on that blue number...

The Big Fix

THE RAINCOAT THAT ACTUALLY KEEPS YOU DRY

PROBLEM

Waterproof jackets aren't good multitaskers. Sure, vinyl or PVC slickers are impenetrable, but while they keep rain out, they lock sweat in—making you feel clammy. One fix is the waterproof breathable jacket. The key to its success is a delicate membrane sandwiched between two layers of fabric. Unfortunately, during downpours, the outer layer soaks through, making you feel damp. And adding to the discomfort, the glue that holds the fabric layers together ends up trapping perspiration inside.

SOLUTION

The Columbia OutDry EX Diamond Shell (\$599+) puts its waterproof breathable membrane on the outside. A grid pattern of abrasion-resistant polymer protects it from the elements. Because the membrane is heat-fused with the polymer and the inner fabric layer, it does away with sweat-trapping glue. If you do work up a sweat, the inner layer wicks it away through the outer membrane. It works so well that Columbia plans to use this same construction on its down jackets, which were previously hard to protect. **BERNE BROUDY**



The Little Fix

TINY-TOOL TAKEOVER



Emergencies rarely announce themselves, so carry all you'll ever need in your pocket.
LINDSEY KRATOCHWILL



1 MACHINE ERA TITANIUM MULTITOOL

Machined, as its name implies, from a block of titanium, this multitool has a Phillips-head and flat-head driver, a pry wedge and both a 1-inch and a 2.5-centimetre rule. A hand-blasted matte finish defies scratching.

2 METAL DREAMER PINCH

It's hard to imagine this titanium chunk encompasses 11 tools—including a wire stripper, nail puller, hex-bit holder, and bottle opener. Despite the sparse look, the company designed it with function in mind—there's plenty of space to hold it.

3 PANGEA DESIGNS PICO

This extremely minimalist item by Pangea is crafted to be a bottle opener. You'll hardly notice PICO in your pocket—it weighs about as much as two paperclips, and keeps a low profile because the key ring it dangles from doubles as leverage.

4 REDUCTIVIST RINGTOOL

Be prepared for emergency bike adjustments. Each of the eight hex-head and driver pieces is long enough to reach screws, and won't be uncomfortable in your pocket. Plus, you can use it as a handy bottle opener.

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Standout

A LEAN, MEAN STREAMING MACHINE



There's a truth (universally acknowledged) about home entertainment: Slow speeds kill your buzz. Everyone hates buffering (when streaming movies) and image stuttering (when playing video games). Nvidia has solved both problems in one device. It's a 4K video-streaming set-top box that doubles as a gaming console.

The Nvidia Shield uses a mighty Tegra X1 processor, the fastest mobile chip on the planet; it has 256 CPU cores that can run at 1 teraflop. What does that mean? For gamers, it's no more lag when questing for monsters in *Upcoming Monster Hunting Game 4*. For movie buffs, it's seamless video playback.

The Shield runs on Android TV, an operating system that syncs to the Google Play store, which offers downloads for movies, music, games, and more. The Shield also has a handy Google Voice search built into the console, so it can answer questions nobody ever asks like, "Do I need my umbrella today?" Sports scores, stock reports, and breaking news are also available via voice command. You can get all the information you need for the day just by asking for it. And because the streamer can act as a Chromecast, it's easy to mirror anything from your Android phone or tablet.

A pencil-thin remote and gaming controller ship with the device, and provide wireless access to all its functions. The Shield comes with a gigabit Ethernet port—which means it can handle ISP speeds no Australian will ever experience—so you'll probably never touch the limit of this machine. That kind of Internet throughput, combined with the blazing-fast Tegra X1, ensures the Shield will never hit a speed bump.

DAVE GERSHGORN



NVIDIA SHIELD

Inputs Gigabit Ethernet, HDMI

2.0, USB 3.0x2, Micro-USB and MicroSD ports

Audio 7.1 and 5.1 surround sound audio output via HDMI

Storage 16GB and 500GB

Operating System Android TV

Connections 802.11ac Wi-Fi, Bluetooth 4.1

Price \$399 for 16GB, \$499 for 500GB version (estimated)



4K VIDEO!
PLUS
GAMES!

HAS WIRELESS CHARGING FINALLY COME OF AGE?



Despite being one of the most useful, yet underrated features included in a growing number of mobile devices, wireless charging is not a new technology. In fact Nikola Tesla experimented with energy transmission without wires as far back as 1891.

Of course Tesla was trying to figure out a way to provide wireless power to the entire world. While the wireless charging tech isn't yet that good, a range of companies are working to take the latest gadgets totally cord-free.

The Qi standard is currently used in smartphones and tablets to provide short range charging via inductance (magnetic coils embedded in device and charger).



The newer **Rezence** wireless charging standard uses magnetic resonance instead and promises more flexible charging options with longer range and higher power capabilities. Backed by big names such as Intel and Samsung, Rezence could also juice-up laptops and even electric cars in the future.

One of the major problems with existing wireless charging is that it doesn't work through metal-skinned gadgets, such as the iPhone. Thanks to Qualcomm, the latest devices will be able to use magnetic resonance to charge no matter what material they are made of.

Other companies are also jumping on the wireless charging bandwagon. From charging pads built into furniture to power banks, here are some of the best options out there to get a wireless charging fix. **LINDSAY HANDMER**



IKEA WIRELESS CHARGING

Due for Australian launch in late 2015, Ikea offers a range of furniture options with built in wireless charging. The system uses the Qi charging standard, but will option Rezence in the future. The range includes, tables, lamps and standalone pads.

SAMSUNG SE370 MONITOR

The latest Samsung monitor now also doubles as a wireless charger. Topping up a phone is as easy as dropping it on the stand. The monitor uses the Qi wireless charging standard, which is compatible with the majority of wireless charging smartphones currently available.



LUXA2 TX-P2 POWER BANK

Furniture that can juice up a phone is all well and good, but sometimes a portable option is handy. The TX-P2 from Luxa2 couples Qi charging technology to a slim 10,000 mAh battery. Charging a phone is as simple as placing it on top, though it also has dual USB ports.

The Colour of Magic



Jeans fade. The sun breaks down the dye's chemical bonds, or the machine washes it away. The same cannot be said for a parrot's feathers. Those striking blues and greens come from "structural colour." Nanoscopic balls of pigment reflect certain wavelengths of light but not others, creating colours purer than any dye. And since there are no chemical bonds to break, the colours can't fade. For the first time, in May, researchers created structural colour in the lab. They say it could lead to longer-lasting paints or even colour-changing camouflage. **LEVI SHARPE**



08

Percentage of men of Northern
European descent who can't tell red
from green, according to the
National Eye Institute

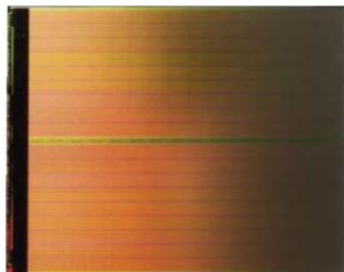
Paradigm Shift

CODE NAME SKYLAKE

The latest technology from Intel brings faster, more efficient computing

Buried inside every computer is the brain - a Central Processing Unit (CPU) that does all the number crunching. In the never ending quest for better performance, Intel has redesigned the PC's CPU with a new architecture. Older slower features have been cut, leaving more room for the cutting edge. The result is a computer that can do more for the same money. It also means Intel can implement the latest features, such as USB Type-C. The changes are also very important to power users like gamers, 3D artists and videographers, who are always looking to push the bounds of performance.

LINDSAY HANDMER



A COMPUTING REVOLUTION

Working quietly behind the scenes, Intel (partnered with Micron) has made a major breakthrough in the future of computing technology. Currently most computers are limited in how quickly they can save or read information, and each time it wears out the storage medium a little until it eventually fails. The new technology, dubbed 3D Xpoint, is up to 1000x faster than existing storage. It's also a lot more robust and will last a lot longer before needing to be replaced. While it might not seem like much, Xpoint is the first wholly new technology (as opposed to iterations or improvements to existing technology) to come to computers since the 1980s. Perhaps most importantly, it's not just a lab-proven experiment that "could be in the PC of the future": it will go on sale in 2016.



Cutting Cords

Intel is part of the Alliance for Wireless power - a collection of companies that want to power all electronic devices without cords. For now the technology is still being improved, but the new lower power systems made possible with Intel Skylake are designed to be able to be charged wirelessly. While it's not quite a reality yet, in the future laptops and tablets may never need to be plugged in again.



THINNER, LIGHTER, FASTER LAPTOPS

Skylake is not just about desktop computers - laptops and convertible tables such as the Microsoft Surface will also get the new tech. The improved CPUs use less power than their older brethren, which means mobile devices can have a longer battery life. It also means they produce less heat, and can be built thinner and lighter. Despite this, a laptop powered by Skylake will also be more powerful. Special low-power versions of the CPUs will even let some laptops and tablets ditch their cooling fans completely, for silent running, ultra-long battery life and no moving parts to wear out, fail or clog with dust.



BETTER STORAGE

One of the biggest bottlenecks of modern computing is how long it takes to store or access data stored on a computer. The new Intel architecture introduces new technology that helps speed up the transfer of information. One of the most important upgrades is USB 3.1. For a start, it ditches the older plugs for the new USB Type-C connector, which is stronger and can be plugged in either way around. It's also a lot faster - twice as quick as existing USB 3.0, and 20 times the speed of the older but still common USB 2.0. The new USB standard can also provide up to 100 watts of power. This allows devices such as laptops to be charged by USB as easily as a phone.

GRAPHICAL GOODIES

While pure number crunching ability is great, the new PCs with Skylake inside will also have better graphical abilities. Each CPU has an onboard graphical processor (GPU) that takes care of actually displaying all those pixels on a monitor. It's actually more important than it seems, as a more powerful GPU lets certain programs (such as those from Adobe) can use the extra processing power to make image and video editing faster. Casual gamers can also rejoice, as this Iris Pro graphics system is now powerful enough to run most modern titles.

Importantly, the new GPUs can run multiple monitors. For example, a high-powered work laptop could support three screens for multitasking in the office, while keeping the on-the-road portability.



Dava Newman

On Getting People to Mars in One Piece



Aerospace engineer Dava Newman has devoted her career to figuring out how we might live in space—suspending subjects from the rafters of her MIT lab to study reduced gravity and designing a flexible, self-mending space suit. As NASA's new deputy

director, she is now tasked with the planning and policy that will make greater human space exploration possible. That means leading the agency's 18,000 employees and 40,000 contractors toward a successful crewed mission to Mars by the 2030s.

"If everyone isn't talking about our journey to Mars at the dinner table, I want to change that."

21

Number of Mars missions NASA has launched since 1960—of which 15 were successful

“

Right now, we have five rovers and orbiters exploring Mars. A human mission is a different ballgame. You have to think about stuff like access to water, psychological impact, radiation, and what happens to your muscles and bones in three-eighths of Earth's gravity. Those are the kinds of things we're trying to figure out on the International Space Station. The twins experiment, for example, will compare the vital signs of the Kelly brothers—one in space and one on Earth—to see physiological and genetic differences.

After the ISS, the next phase will be to go beyond low-Earth orbit into cislunar space, the region between Earth and the moon. That will be a proving ground in the 2020s. Then, we'll move into the neighbourhood of Mars. Before we go to the Red Planet itself, we might want to go to one of its two moons. There's plenty to learn from landing there since the physics is different from here.

Because of orbital mechanics and the way Mars and Earth revolve around the sun, the two planets are nearest to one another for about 30 days, once every 26 months. That means the four- to six-member crew could stay on Mars a month, or they could stay until the next window, two years later. I think it makes sense to spend a lot of time on the surface because the trip is so long—seven months and 350 million miles, give or take.

We have 15 different tech road maps to get there. Because of the budget cycle, we can't afford all of them, so we're focusing on eight, including propulsion, entry, descent and landing, and life-support systems. And, of course, there's education.

For students today, Apollo is ancient history, yet they all want a selfie with the astronauts. The magic of NASA is that it still has a cool factor for young people. That's important because they're going to be the ones who actually set foot on Mars.” **AS TOLD TO HEATHER HANSMAN**



A Hub Away From Home

↓

An Airstream offers retro appeal, but it can't compare to the sustainable, high-tech glamping you could do in an Ecocapsule. Developed by Slovakian firm Nice Architects, the portable living space runs on sun, wind, and rain alone. Throw in a cache of canned food, and you'll be set to hunker down indefinitely. The 4.5-metre, 1.3-tonne pod can serve as a research station, disaster-relief shelter, or remote Airbnb almost anywhere. The second-generation version—which is expected to debut this year and go on sale in 2016—includes sleeping quarters for two, a kitchenette, a shower, climate control, and even electrical outlets. Plus, it comes equipped with a custom-designed H₂O-free toilet that incinerates your waste out of existence. **CORINNE IOZZIO**



Concepts & Prototypes

The Ecocapsule can be shipped, airlifted, or trailer-towed into place.

CONTOURED SHELL

The Ecocapsule's egg shape reduces surface area (and therefore heat loss) without sacrificing living space. You can stay in the pod year-round. Thin aerogel insulation—already used in buildings, water bottles, and spacecraft—is sandwiched between two aluminum-reinforced poly-carbonate walls.

POWER SUPPLY

A 750-watt wind turbine and 600-watt solar array collect energy. Assuming outside temperatures stay between -25° and 40°C , the capsule can consistently produce all its own power. A super-efficient climate-control system helps: On its way to the exhaust fan, heated air passes through channels alongside fresh air, warming it up.

ENERGY STORAGE

Should energy production dip, a 9,744-watt-hour battery holds five days of power. When the battery is charged, the system uses excess energy from the solar cells to heat up water stores, relieving strain on the water heater when it comes to shower time.

RAIN COLLECTION

Rainwater runs down the capsule and through a ceramic filter into a 550-gallon reservoir beneath the floorboards. When full, it can supply two people for three weeks. Electric pumps circulate water through a membrane filter to trap dirt and bacteria en route to the sink and shower; manual foot pumps stand in when energy is low.

SMART INTERFACE

A central computer, controlled with a smartphone or tablet, monitors energy and water levels to project how long they'll last. It's also hooked up to sensors that record rainfall, humidity, and temperature outside the capsule. In periods with little sun or wind, the computer might suggest adjusting the internal temp or taking shorter showers to stretch out the supply.



Your History in a Drop of Blood



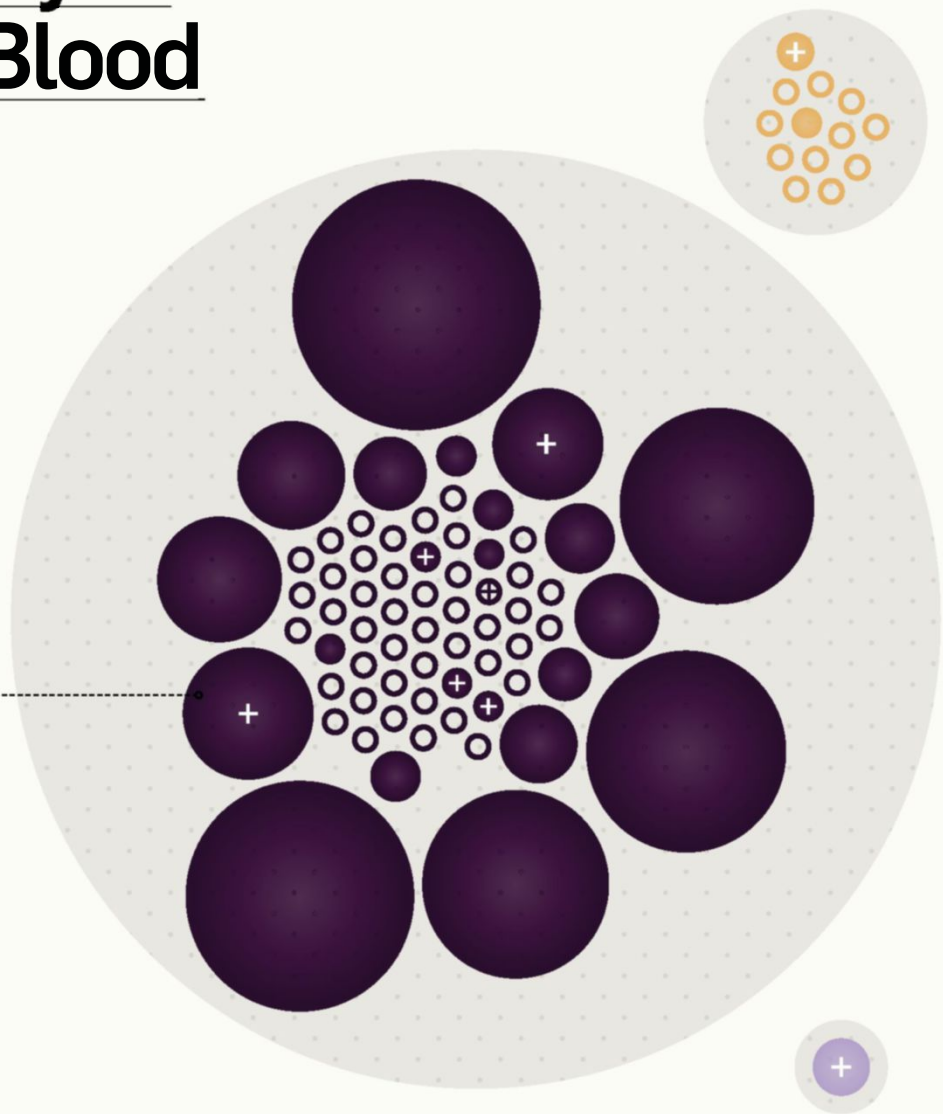
A **blood sample** can now reveal a record of viruses you've had throughout life, thanks to a new test developed at Harvard called VirScan. It looks for evidence of antibodies produced by the immune system to kill viral invaders. "It's kind of like fishing," says geneticist Tomasz Kula. "We've made this huge pond [of viral bits], and we see which ones the antibodies stick to." Here are the viruses they found. **SHANNON PALUS**

SPECIES Human Herpesvirus 3

PREVALENCE 24 per cent

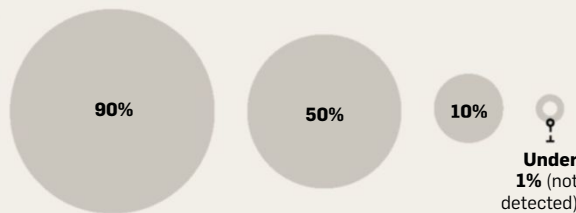
TRAITS The source of chicken pox (and shingles)

Most people contract chicken pox before age 10 or get vaccinated to avoid it. Over time, the number of antibodies drops, so there could be too few for VirScan to detect (hence the low prevalence). This might also mean there aren't enough to fight off the virus if it comes back in the form of shingles during adulthood either.



HOW TO READ THIS VISUALISATION

Each circle represents a virus tested for by VirScan. The researchers ran the test on 303 blood samples from US subjects, excluding any known to be HIV- or Hepatitis C-positive.

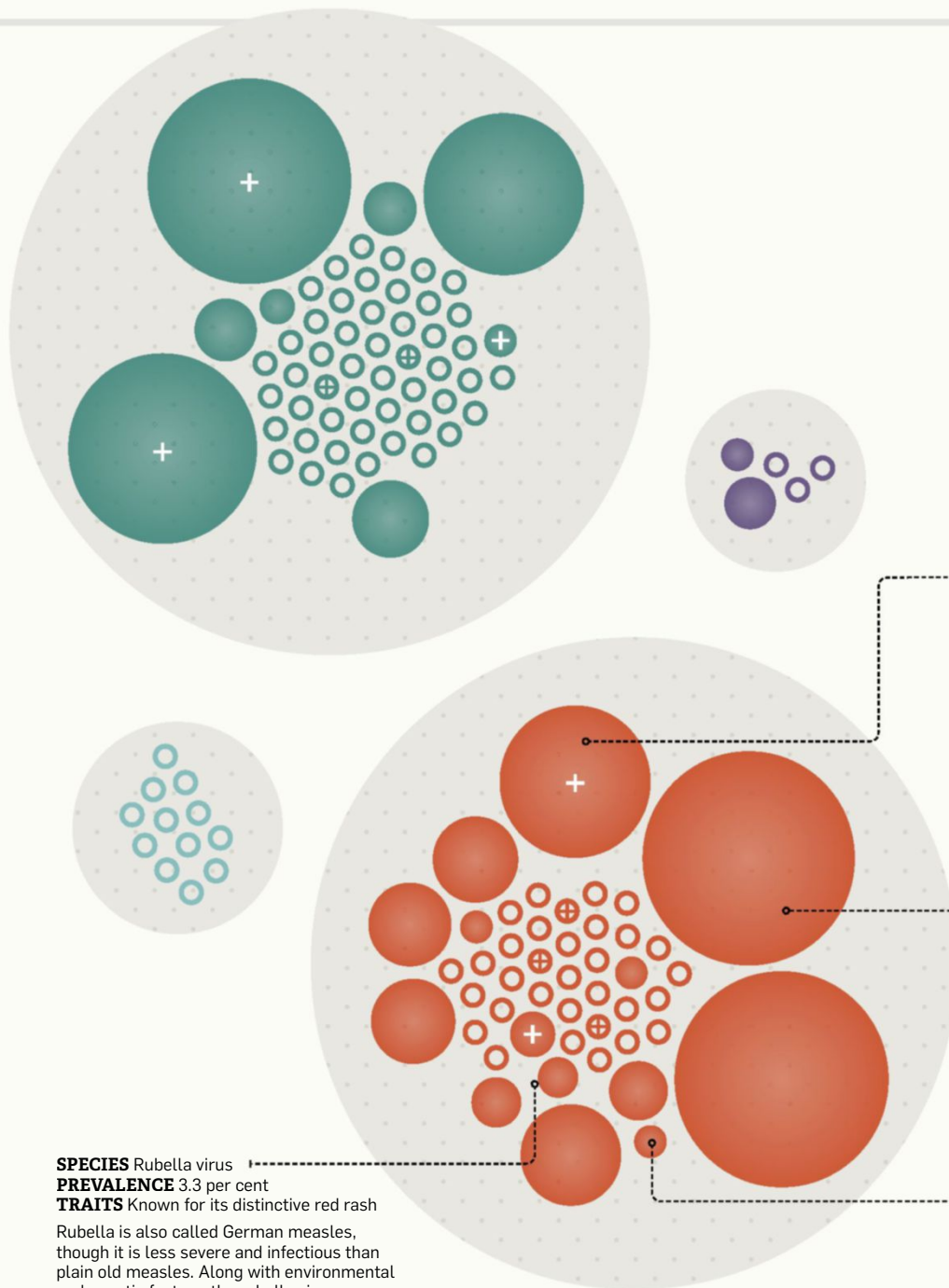


Circle size represents the prevalence, or the percentage of people who had antibodies from the virus present in their systems.

Plus signs mark virus species with FDA-approved vaccines

Colors indicate the virus class, which is based on its genome and how it multiplies.





HOW IT WORKS

VirScan matches antibodies in a person's blood sample to a library of 93,000 snippets of viral code. It can find evidence of up to 1,000 different viruses.

SPECIES Enterovirus C

PREVALENCE 37 per cent

TRAITS Triggers polio, a disease that has effectively been absent from Australia since 1972.

Vaccines during childhood usually prevent the disease, but the protection could fade over time. That's why you still need a booster to travel to one of the few remaining countries where polio still exists.

SPECIES Rhinovirus B

PREVALENCE 75 per cent

TRAITS Responsible for the stuffy nose, sore throat, and sneezing associated with the common cold

Rhinovirus B is more prevalent in children than adults because it spreads by contact, so seemingly innocuous things like shared toys and drool-covered fingers become viral vectors.

SPECIES Hepatitis C virus

PREVALENCE 1.7 per cent

TRAITS Causes Hepatitis C, an infection that is often symptom-free at first

Hepatitis C is not the most common virus, but it is a dangerous one because the inflammation and liver damage it causes can lead to liver cancer.

SPECIES Rubella virus

PREVALENCE 3.3 per cent

TRAITS Known for its distinctive red rash

Rubella is also called German measles, though it is less severe and infectious than plain old measles. Along with environmental and genetic factors, the rubella virus is one of the candidates researchers think could cause multiple sclerosis.

FINDING WHAT AILS YOU

When you're sick, the symptoms need to suggest a particular virus, like the flu, for your doctor to narrow down what to test for. That's because most scans can look for only a single culprit. But some viruses, like Hepatitis C, can cause damage without any outward signs—meaning they can go unchecked for years. A routine VirScan could pick up on these and other rare pathogens so you can seek treatment.

92

Percentage of US kids, age 19 to 35 months, vaccinated for measles, mumps, and rubella in 2013, according to the CDC

SOLVING MYSTERIES

Chronic fatigue syndrome affects millions of people, but the cause is unclear. The CDC has a list of 10 suspects, seven of them viruses, including rubella and mononucleosis. By screening people with and without chronic fatigue, VirScan could collect enough data on their viral histories to determine if and how the viruses might be involved. Only then can researchers start looking into a cure.



For those who didn't read all 184 pages of the Pope's encyclical, here are the highlights:

Praise Be to Science

Science and religion usually make uneasy bedfellows. That's why Pope Francis' encyclical on climate change, published in June, made headlines. The papal essay is the Vatican's first authoritative word on climate policy, and it takes an unequivocal stance: The world needs to act.

Atmospheric scientist Katharine Hayhoe, director of the Climate Science Centre at Texas Tech University, says the Pope's message might prove more effective than 30 years of scientists' efforts to communicate the urgency of climate change. "Scientists used to operate under the assumption that if people don't agree with you, it's because they don't understand," Hayhoe says. "So they thought, 'Oh, we just have to explain it better.'" But social scientists have learned that a simple lack of information doesn't explain disbelief or indifference. "Science can tell us why climate change is happening, and what might happen next," Hayhoe says. "But what we should do about it isn't a science question. It's a question of values."

And that's where Pope Francis comes in. He aligns the science of climate change with a moral call-to-arms. As he states in the encyclical, "Human beings, while capable of the worst, are also capable of rising above themselves, choosing again what is good, and making a new start."

LOIS PARSHLEY

"It's morally irresponsible to suggest there's a debate about the reality of climate change."

—KATHARINE HAYHOE, DIRECTOR OF THE CLIMATE SCIENCE CENTER AT TEXAS TECH UNIVERSITY

1 CLIMATE CHANGE IS REAL
"Climate change is a global problem with grave implications: environmental, social, economic, political..." Francis writes. "It represents one of the principal challenges facing

humanity in our day." While there are still people who deny Earth is warming, the Pope echoes the consensus of the scientific community: Global surface temperatures have increased over the past 100 years. And it's our fault.

2 TECHNOLOGY WON'T SOLVE EVERYTHING
The Pope doesn't object to progress; he acknowledges that science and tech have enriched our lives, and provide us countless benefits. But he notes that advancements don't necessarily improve things across the board. "[O]ur immense technological development has not been accompanied by a development in human responsibility, values, and conscience."

3 WE HAVE TO CHANGE OUR BEHAVIOUR

"An integral ecology is also made up of simple daily gestures which break with the logic of violence, exploitation, and selfishness," Francis writes. On a global scale, that could take the form of an international environmental treaty. "[R]ecent World Summits on the environment have not lived up to expectations because, due to lack of political will, they were unable to reach truly meaningful and effective global agreements on the environment." Here's hoping that the UN climate talks in Paris this December will be different.



17

Estimated average sea level rise, in centimetres, during the 20th century. The rate since 1993 is about twice that of the past century.



Anthony Fordham is the editor of *Australian Popular Science*. In a university Creative Writing assignment in 1999, he predicted that by 2015, mobile phones wouldn't have an off switch.

Good for humanity? These days, coal is barely good for business.

COLUMN BY ANTHONY FORDHAM

One of the great things about trying to predict the future is that if you get it right, everyone thinks you're a genius. And if you get it wrong, people say: well never mind, no one can predict the future.

Anyway, here's my prediction. Three or four hundred years from now, the weird mix of posthuman, AI, genetically elevated animals and baseline humans who are the descendants of our civilisation, will talk about how fossil fuels were used for a brief period to kickstart exponential technological development and growth.

There are many aspects of human behaviour that we can trace back millennia - beer making for instance - but the burning of hydrocarbons to power big machines won't be one of them. Oh sure we've had FIRE forever, and that's technically hydrocarbon-derived energy, but I'm talking about digging up coal or extracting oil and burning it to make stuff go.

When our modern history inevitably becomes ancient history, the fossil fuel economy is going to be a footnote, a blip, a brief century. An important century, sure, the dividing line between the slow and steady growth of the preceding millennia and the sudden explosion of humanity (and our children) outward to the stars. But a blip nonetheless.

The main advantage of fossil fuel is that it gives a civilisation very high densities of stored energy, without the need for especially complex tech to extract it. It gives us the power to go out and do, and grow, and build. It's the chicken of capability, before the egg of technological sophistication.

The main disadvantage of fossil fuel is almost everything else about it. The machines that use it are hugely inefficient. The pollution is hugely damaging. The environmental cost of extracting and using the stuff is very high. The way reserves are concentrated in specific geographic areas leads to conflict. The more of it we use, the more expensive it becomes to extract and process. And the more our technology develops and advances, the less effective and suitable fossil fuels become.

The first cars could run on everything from

YOU DON'T NEED ME TO TELL YOU THERE ARE HUGE VESTED INTERESTS IN KEEPING THE FOSSIL FUEL ECONOMY RUNNING UNTIL THE LAST BITTER BILLION DOLLAR CONTRACT HAS BEEN FULLY EXERCISED

moonshine to bacon fat. Today, a fancy sports car demands Premium 98. Jet fuel is now so expensive, airline companies make only modest profits - if any profits at all. Coal is in this bizarre economic situation where it can make really good money on one side of the planet, and no money at all on the other.

You don't need me to tell you there are huge vested interests in keeping the fossil fuel economy running until the last bitter billion dollar contract has been fully exercised. But while our politicians say ridiculous things about the importance of coal or the safety of natural gas, what we're seeing on a global scale is a tipping of the balance.

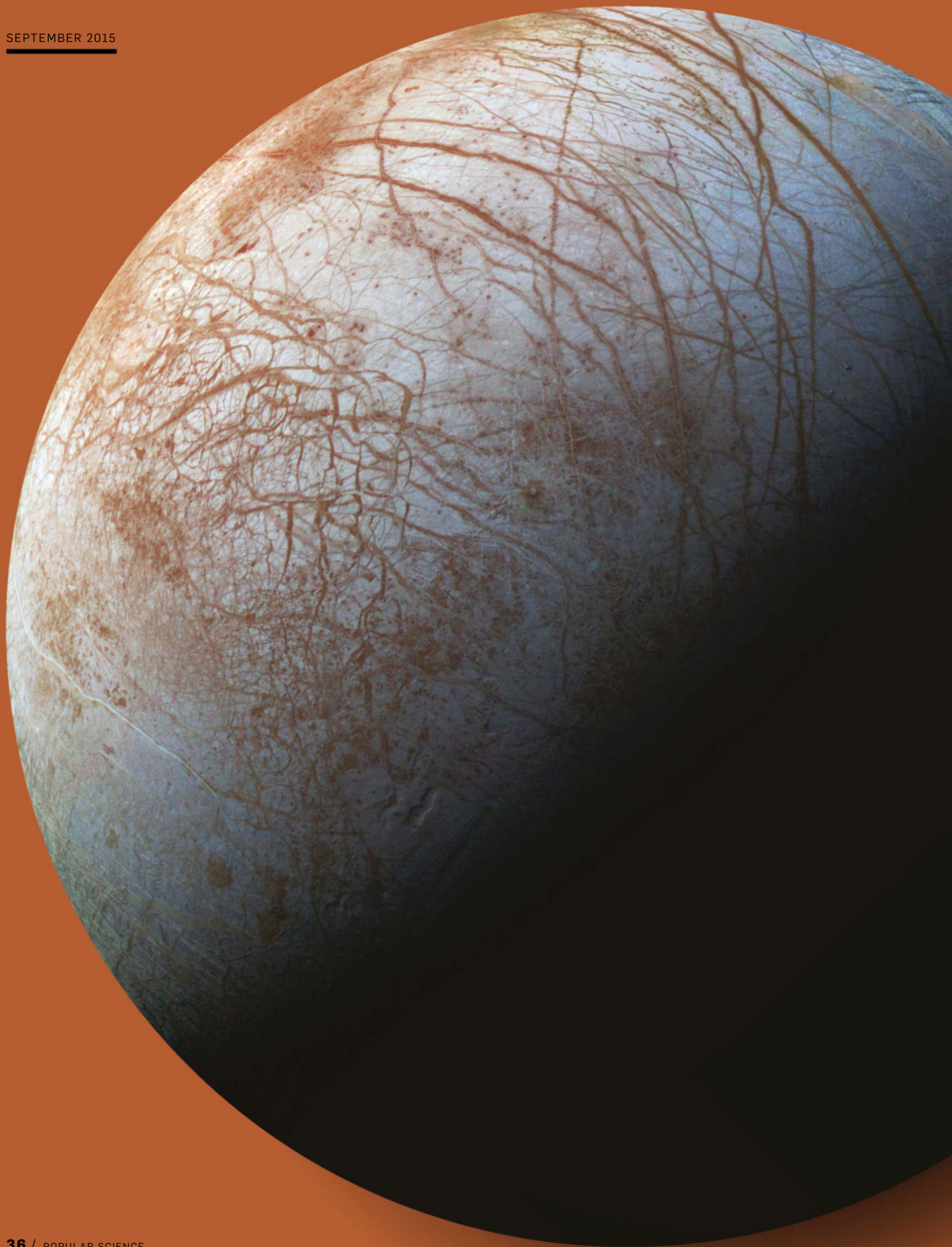
No shrieking greenie protest march is going to shut down a country's dependence on fossil fuel. But a global groundswell of big business investing in alternate technology is. The old energy economy won't die with a bang, but with a whimper.

What's frustrating to me, as a technologist, is that it feels like we're in the middle of an ideological fight that's just pointless to have. Why wait for an energy crash when affordable reserves of coal or oil run out? Why not develop and integrate the tech we know can replace them, at a pace determined by an appropriately regulated economy?

Those last two questions were rhetorical, by the way, because that's exactly what is happening. Thirty years ago, people scoffed at wind and solar, saying "those technologies are thirty years away at least". Well here's a prediction that I feel pretty confident about: one day it will be 1 January 2100. The future always comes around. You just need to ask yourself: do you want to be on the side of tomorrow, or yesterday?

147

Years of proven coal reserves in the world, assuming consumption remains steady
Source: British Petroleum, 2007 report





EU

RO

JUPITER'S MOON MIGHT HOLD THE LIFE WE'VE LONG SEARCHED FOR DEEP IN ITS HIDDEN OCEAN. AND SCIENTISTS HAVE ONE SHOT TO REACH IT.

PA

OR BUST

BY COREY S. POWELL

The search for alien life has recently taken a surprise twist away from Mars and toward Europa, an ice ball of a moon in orbit around Jupiter. To understand why, you just need to look at these three numbers:

ZERO

1.33 BILLION

3 BILLION

The first is the known volume of liquid water on Mars (sorry, permafrost and billion-year-old riverbeds don't count). The second is the volume of water on Earth, measured in cubic kilometres. The third is the inferred volume of water sloshing around just beneath Europa's frozen surface. Sure, Mars may have had an ocean billions of years ago, but Europa has them right now—and they are more than twice as voluminous as ours.

Everything we know about life says that it needs water. Concomitantly, every place on Earth where water exists, life does too. The conventional thinking, then, is that if you want to find alien life, the first thing you look for is alien water. Europa is the wettest known world in the solar system. Life also needs food and energy. Europa scores there too: Its ocean might be nourished by a drizzle of organic chemicals and stirred by volcanic vents like the ones dotting the mid-Atlantic ridge. If any place in the solar system holds the answer to the question "Are we alone?", it's a good bet that Europa, not the Red Planet, does.

Which is not to say that getting the answer will be easy—not by a long shot. To give you a sense of exactly how hard it will be, consider three more numbers: 965 million—the average flight distance, in kilometres, from Earth to Europa, meaning that the journey there could take at least six years; 500—the average radiation dose, in rem per day, on Europa's surface, enough to fry unprotected spacecraft electronics within a matter of days; and 16—the average estimated thickness, in kilometres, of Europa's ice shell; more than four times as thick as the ice sheet covering Antarctica. Overcoming those numbers will test the limits of human ingenuity. But a growing chorus of scientists has argued that we must try.

This past May, NASA finally agreed and began the development of a probe to visit Europa sometime in the next decade. Many details of the mission, including its name, remain undecided. But NASA has selected the nine scientific

instruments that will ride aboard the craft to collect data, and Congress has put up the cash to get the potentially US\$2 billion project underway.

For the Europa faithful, this news has prompted celebratory toasts, along with more than a little giddy disbelief. "We understand how special Europa is. It's worth the investment. It's worth the risk," says Louise Prockter, a planetary scientist at Johns Hopkins University's Applied Physics Laboratory. Prockter has already made that investment herself, having spent half her career studying Europa's unique, frosty terrain. "I just hope we can get something there while I'm alive."

SOMETIMES GREAT discoveries begin with what you do not see. Such was the case when *Voyager 2* flew past Europa in 1979. It radioed home images revealing a world as white as a glacier, slashed with enigmatic brown streaks, and utterly flat. "No craters. It just looked like a huge ice pack. That was a big surprise," recalls Ed Stone, *Voyager's* long-serving project scientist. A lack of craters indicated a fast-changing surface that quickly erases the scars of asteroid impacts; that, in turn, implied that there must be some unrecognised energy source driving the activity. We know now that Europa's gravitational interactions with Jupiter's other large moons and the gas giant itself, stretch and squeeze its interior, producing frictional heat (like rubbing your hands together) and creating a vast, warm ocean. The ice pack is merely frosting on top.



This close-up of Europa, taken by *Galileo* in 1997, has been color-enhanced to reveal surface features. Blue-white terrain shows relatively pure water ice; reddish stripes may contain salts from an ocean.

Eight years after *Voyager's* flyby, the writer Arthur C. Clarke was still so captivated by the discovery that he set his novel *2061* partly on Europa. He imagined it as a world inhabited by primitive aquatic creatures and guarded by the monoliths from *2001: A Space Odyssey*. In the previous novel, 2010, they had issued a warning to humans: "All these worlds are yours—except Europa. Attempt no landing there." Among planetary scientists, these words have become both an in-joke and a taunt.

In 1995, NASA's *Galileo* spacecraft went into orbit around Jupiter, and Europa came into sharper focus—up to a point.

A series of new, much-closer images showed the moon's streaks appear to be glacial fissures that have been flooded from below. Other regions resembled sea ice that has broken apart and refrozen. But *Galileo* was hobbled by a faulty radio antenna that restricted its data transmissions to a trickle. Over much of Europa it was unable to capture any details finer than roughly 1600 metres wide, and the probe left some regions almost entirely unmapped. No other spacecraft has gone to visit since the *Galileo* mission concluded in 2003.

Prockter has made the best of a difficult situation, meticulously knitting together the two-decade-old imagery to show that Europa's surface ice circulates down to the warmer layers below and back up—a colder version of Earth's plate tectonics. Britney Schmidt, an astrobiologist at Georgia Tech, has found evidence of Lake Erie-size bodies of water embedded within Europa's

If any place in the solar system holds the answer to "Are we alone?" it's a good bet Europa does.

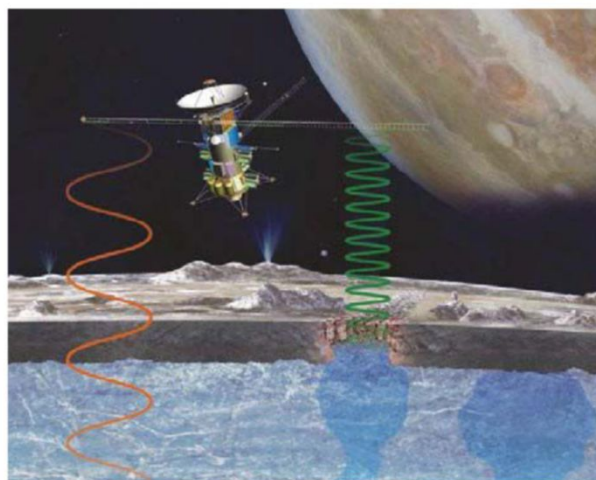
crust that could act as conduits between ocean and surface. Taken together, these discoveries point to an intriguing model. As the crust slowly churns, the surface ice could transport oxygen, minerals, and organic chemicals deposited by comets into the ocean depths. Meanwhile, upwelling ice or rupturing lakes might carry evidence of life to the surface. "If we can really understand how the ice shell works, that will tell us about Europa's ability to support life, about where to look," Schmidt says.

Recent long-range studies have added to Europa's mystique. Nearly two years ago, researchers working with the Hubble Space Telescope sighted a huge vapour cloud hovering over Europa's southern hemisphere. Evidently liquid water is able to break through the crust and blow into space, meaning that either there is water close to the surface or there are very deep cracks in the ice. Also, this past May, a team at NASA's Jet Propulsion Laboratory (JPL) reported on experiments that reproduced the red-brown colour of Europa's streaks: The markings seem to be the result of oceanic salts that reached the surface and were discoloured by Jupiter's radiation. A salty ocean is just what you'd expect if water interacts vigorously with a rocky seabed, picking up dissolved salts. And well-stirred mineral-rich waters bode well for life.

All of which would make Europa a fascinating destination even if it were a freaky outlier, but it isn't. Broadly similar icy worlds—including moons, dwarf planets, and giant asteroids—are the norm in the vast outer zone of the solar system. According to the latest research, at least nine of these bodies have inner oceans too. Even Pluto might be wet on the inside, a suspicion bolstered by the 3,000-metre ice mountains and other dramatic surface geology recently found by the *New Horizons* probe. Put another way, most of the liquid water in the solar system is found not on the surface of rocky worlds like Earth but inside icy bodies like Europa. That raises the stakes for NASA's upcoming mission. If we find evidence of life on Europa, it would point to a whole new class of habitable worlds across the solar system, and probably across the universe.

PRETTY MUCH FROM the moment *Galileo* reached Jupiter 20 years ago, Europa proponents have been thinking about how to go back and study the moon in proper detail. Along the way, they have worked on three separate mission concepts that NASA initiated and then cancelled. At this point, they know the challenges of Europa backward and forward.

Distance is the simplest one to address because it has a straightforward, brute-force solution. Using an off-the-shelf Atlas V rocket, the voyage to Europa would take at least six years—a painfully long time for academics and political supporters alike. The current Europa concept therefore calls for hitching a ride on NASA's upcoming rocket, the giant Space Launch System (SLS). In its initial configuration, SLS will be 97 metres tall and pack three million kilograms of thrust. That's good enough to potentially cut the travel time to Europa at least in half. In NASA's current schedule, the first SLS will



The Europa probe will carry a radar that emits both short and long wavelengths. These will penetrate the moon's shell to measure the ice and detect pockets of water.

be ready for a test flight in 2018—plenty early for a Europa mission, which is provisionally slated for launch in 2022.

Dealing with radiation is trickier. An earlier Europa mission concept included a heavily shielded orbiter that was designed to survive the nonstop barrage of energetic particles near Jupiter. Partly for that reason, the probe was estimated to cost a hefty US\$4 billion-plus. A team including Robert Pappalardo of JPL came up with a simpler, cheaper solution: Ditch the idea of orbiting Europa and instead settle into a straightforward orbit of Jupiter as a whole. As the probe whirls around the giant planet, it will fly past Europa about 45 times, skimming as close as 25 kilometres above the surface. After each pass, it will quickly retreat to a more distant part of its orbit, where radiation levels are drastically lower. The team estimates that the cut-and-run approach will easily allow the probe's electronics to survive the intended three-year duration of the mission.

But radiation creates an informational challenge in addition to the physical one. Even if there is life on Europa, and even if circulation of the ice sometimes carries ocean organisms to the surface, Jupiter's magnetic field blasts them with energetic particles as soon as they are exposed. Those particles break down organic molecules, so it would be difficult to detect intact traces of alien microbes lying on Europa's surface. (A beached European whale? Maybe. But nobody is banking on that.)

Fortunately, Europa itself has provided a solution. The icy plumes might eject water samples as high as 200 kilometres above the surface—well within the probe's flight path. A group of scientists recently convened a workshop called "Potential for Finding Life in a Europa Plume" to figure out how to take advantage of this discovery. Forget about finding intact microbes, they concluded. Even if Europa's ocean waters are as rich with life as Earth's, the odds of scooping up a living cell are minuscule. Oh, and the craft will be moving about 16,000 km/h relative to the plume; any bits of ocean, and any organisms in it, will hit at six

Any bits of ocean or organisms will hit the probe at six times the speed of a bullet from an AK-47.

Our Watery Neighbours

Where there's water, there's the possibility of life. And a surprising amount of water can be found throughout the solar system. Scientists have now identified at least nine worlds other than ours that likely have warm inner oceans.



CERES

Nearly 25 per cent of the dwarf planet is made up of water ice, and a fraction of that could be liquid.



EUROPA

There is strong evidence of a salty, circulating ocean just beneath this Jovian moon's ice shell.



GANYMEDE

Jupiter's biggest moon may have saltwater inside; a 2022 European probe plans to investigate.



CALLISTO

Under a 100-km-thick crust, this Jovian moon may have an ocean deeper than any on Earth.



ENCELADUS

Jets of water seen on Saturn's moon Enceladus seem to be fed by an ocean under its south pole.



TITAN

A salty ocean lurks inside Saturn's largest moon; up top, there are lakes of liquid natural gas.



MIMAS

Another moon of Saturn, Mimas hides either a subsurface ocean or a foot-ball-shaped core.



TRITON

The features on Neptune's moon Triton imply it may have had an ocean—but possibly no longer.



PLUTO

New Horizons spotted geologic activity on the dwarf planet that might be driven by an inner ocean.

might be possible to spot flash-frozen, life-bearing seawater (or at least chemistry) on the European surface before it gets irradiated beyond recognition. The probe will carry a radar to seek out regions of thin ice, where eruptions might have occurred in the recent past, and a device called an imaging spectrometer to scan the surface composition in detail.

In the end, though, Europa's plumes might give merely circumstantial evidence. The better way to get answers—the one that puts a gleam into the researchers' eyes—is to ignore Arthur C. Clarke's monoliths and send a lander.

WHAT WE WILL FIND if we touch down on the surface of Europa is anyone's guess. Humans have never landed on an ice world before. The closest analogues are the Earth's Arctic and Antarctic regions, but in many ways the resemblance is only superficial. Pappalardo points out that Europa is far colder, with highs never rising above minus 135 degrees C. At those temperatures water is as hard as concrete. Radiation erodes the surface in unpredictable ways. In short, we have almost no idea what kind of surface we'd be landing on.

Adam Steltzner, the JPL engineer whose team designed the insane-genius "skycrane" landing system for the Mars *Curiosity* rover, is ready to design a Europa lander all the same. He notes that the engineers didn't know the surface landscape of Mars when the Viking landers descended in 1976, and they did just fine. Touching down is, literally, just a matter of rocket science. "It's how much weight you can carry," he says, "how much power, how big of a retro-rocket." If you want the lander to last more than a few days, you also need a lot of radiation protection. The heavier the lander, the bigger the thrusters you need to go from 19,000 km/h in orbit to 0 km/h on touchdown. And you'd need the primary orbiter to scout out good sites before releasing the lander. Hard jobs, but there are no showstoppers from the engineering side.

Steltzner already has some clever ideas about how the lander might go about its scientific work. Extracting samples from the frozen European surface would not require a costly power drill, he notes; the lander could do the job more elegantly by using its onboard power supply to run a heater in one of its legs. A little warmth would be enough to melt and vaporise the underlying ice. Then the lander could suck the fumes up through the leg, draw them through a mini chemistry lab, and look for signs of life. As the lander settles it would perform a tiny excavation, burrowing through the irradiated surface into the more-intact ice below.

NASA has also invited the European Space Agency to submit a proposal for a Europa lander or a high-speed ice penetrator—basically a javelin thrown into the ice. Any of these ideas would have to go through a review process, and probably would not be formally approved until 2016 or 2017. There is also the matter of money: NASA has no funding for a Europa lander, although several members of Congress support the concept.

The great fear of the Europa believers is not that the challenges of visiting this ice moon are too daunting, but that the process of rising to them will simply be too costly. Mars is closer, more accessible, and more familiar; if you just crunch the budget numbers, that's the place to go. But Europa is the world with the winning scientific numbers. If we invest the time and money, a mission to Jupiter's ocean moon could yield the most exciting figure of all: 2, the number of places in the universe where we know that life exists. **PS**

times the speed of a bullet from an AK-47.

The researchers are optimistic all the same, for two reasons. First, finding chemical signatures of life is far easier than finding an intact alien bug. With that in mind, a pair of miniature labs aboard the probe will aim to measure the composition of the plume as it flies through. Second, it

Dangerous Curves



THE SCIENCE OF A GREAT DRIVING ROAD

BY LINDSAY HANDMER

Fans of, shall we say, lifestyle driving programs like Top Gear are familiar with the various hosts' various quests for "the perfect driving road". Big budgets and friends prepared to lend them supercars, see doughty British chaps travel to the ends of the Earth (usually an ex-communist country) to carve up and down a mountainside while exclaiming how wonderful the experience is.

But is this all theatre? Or is there fact behind the frothy adjectives? Are some roads scientifically, empirically, measurably superior to others - that is, if your motivation is having a fun time behind the wheel of something light and whippy?

A proper driving experience - as opposed to a mere commute or road trip - is a delicate yet exhilarating dance between a host of different forces, from lateral cornering gees to hard acceleration. Different roads and cars each have a unique style and can be matched for the best experience. We took four very different cars and paired them with four of our favourite roads to see what science could tell us about great driving.



The Science of Motion Sickness

Driving fast through a twisty road is always fun for the driver, but sometimes the passengers can suffer. Next time that nauseous feeling sets in, think about how motion sickness is actually thought to be a defence mechanism against poisoning. The feeling is caused by a disagreement between the visual perception of motion and what is felt in the inner ear. In other words, the senses of sight and balance don't agree. The brain doesn't know which sense is giving out the incorrect information, so assumes it has been poisoned by something eaten (usually a mushroom-delivered neurotoxin). The next logical step of course is to induce nausea, to first prevent you from eating any more of the bad toadstools, and then even vomit, in an effort to clear out anything that could have caused the sensory mismatch. Motion sickness is hard to cure, but "placebo" treatments like a band-aid across the belly button (yes, really) can assist in beating the condition through mind-over-matter.



Avis Formula

Rental car company Avis turned to science to figure out which roads around the world are the best to drive. Teaming up with a quantum physicist and F1 and rollercoaster track designers, the researchers think they cracked the perfect formula. The key parts to a good drive are bends, acceleration, cruising and braking. Bendy roads and fast acceleration are fun, while longer straight sections are more relaxing and scenery-focused. After crunching the numbers, it turns out that the secret is a 10:1 ratio: 10 seconds of straight, for every 1 second of curve. From those numbers, the team identified the N-222 from Peso de Régua to Pinhão in Portugal as the world's best driving road.

➤ The Physics

First things first - unless you're prepared to pay house money, there is no car that is perfect for every single road. A big fast heavy car can be smooth and solid through big sweeping corners, but feels sloppy and even barge-like when it comes to more precise manoeuvres. Likewise, a smaller but nimble car can be amazing when thrown through a weaving twisty road, but lacks that right-foot oomph you crave once the terrain opens up. Getting the most from the driving experience is all about matching roads to cars, for just the right combination of g-forces and average corner radii.



➤ The Method

To compare cars and roads, we used Google Maps to measure the curvature of the corners on some of our favourite roads. From there we tracked our lateral acceleration while actually on the road and recorded the maximum figure. Of course, the g-forces are significantly under the maximum the cars could achieve before losing traction - these are public roads. A well set up vehicle can hit around 1g lateral acceleration in ideal conditions. In practice, we saw less than half of that, depending how tight the roads were.



➤ The Longest Way Around

Right here in Australia we have the longest national highway in the world. Circling the country (as well as a section through Tasmania), National Highway 1 covers a massive 16,000 km. To put that in perspective, driving 10 hours a day (at the various speed limits), it would still take a month to make it around. Some amazing scenery and drives are included in the National Highway 1, such as the Great Ocean Road. The first car trip all the way around Australia was completed in 1925 and took five months. The car of choice was a second hand 1923 Citroën 5CV that already had 48,000 km on the odometer, driven by 22 year old Nevill Westwood.

Dangerous Curves



- ❶ **CAR:** Audi S3 Convertible
- ❷ **ROAD:** Great Ocean Road
- ❸ **CORNERS:** Tight to Sweeping
- ❹ **MAX G-FORCES:** 0.48 g

THE ROAD

The Great Ocean road is one of the most iconic drives in Australia. Over 240 kilometres of tarmac wind along the Victorian coastline before plunging through the hills and forests and ending up at the eight stone pillars we call the 12 Apostles. The road was actually built by soldiers returning from World War 1, and also functions as the largest war memorial in the world.

THE CAR

The Great Ocean Road is all about the coastal views, sunshine and fresh ocean air, so a convertible is the obvious choice. But don't be fooled, the A3 is no cruiser - with 210 kW and AWD, the feisty little car is just as happy being driven hard. The six-speed dual clutch auto is a joy to use and the exhaust note sublime.

The S3 also has all the bells and whistles, with a full entertainment and navigation system as well as an array of external sensors. Two features most useful for road trips are adaptive cruise control, as well as active lane assist. With both turned on, the Audi simply matches the speed of the car ahead (up to the preset maximum) and will even brake down to a complete stop if traffic slows up. Lane assist uses a camera to track the edges of the road and will gently guide the car back into the lane if the driver drifts. It sounds invasive, but is actually very relaxing and helpful on longer, boring straight roads.

Pulling over while the soft top drops (though it can be raised and lowered up to 50 km/h) gives a chance to admire the view, as well as drop behind the slow coaches.

SISTER ROAD WORLDWIDE

Big Sur, California, USA

Winding along 140 km of rugged California coastline, Big Sur gives spectacular views out over the Pacific Ocean. Unlike the Great Ocean Road, there are no urban areas, with mostly (nearly) unspoilt wilderness. The road hugs the Santa Lucia Mountains, and ranges from near sea level to skirting cliffs hundreds of meters high.



SPECS

Engine: 2 Litre Turbo
Power: 210 kW
Torque: 380 Nm
Drive: AWD
0-100: 5.5 seconds
Weight: 1450 KG
Price: From \$70,000

Dangerous Curves

THE ROAD

Nearly 1000 km of highway link Sydney and Brisbane along the coast, but one of the best stretches is just outside Sydney, from Berowra through to Gosford. Winding through sandstone mountains, across waterways and through valleys, the 40 km stretch of road is a tight, challenging and oh so fun. Popular with motorcyclists, its best visited during the relatively empty weekdays. For a longer loop, head back to Sydney via Wisemans Ferry Road along the Hawkesbury River.

THE CAR

The Ford Focus ST is small, light and agile, with enough power to make the trip fun without getting out of hand. This 184 kW turbo front wheel drive car can exhibit some fairly aggressive torque steer, but is aided on the road by the smart torque vectoring system. Pushing hard into a

SPECS

Engine: 2.0L 4 Cylinder Turbo

Power: 184 kW @ 5500 RPM

Torque: 360 Nm @ 2000-4500 RPM

Transmission: 6 Speed Manual

Economy: 7.3 L/100KM

Price: \$38,990

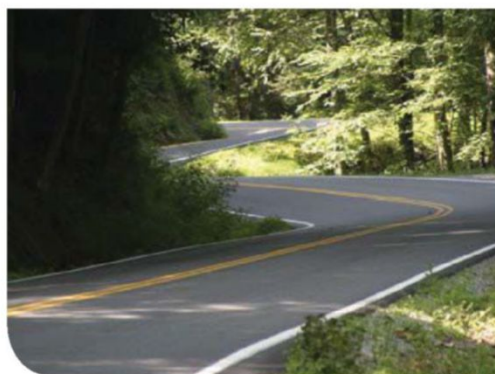
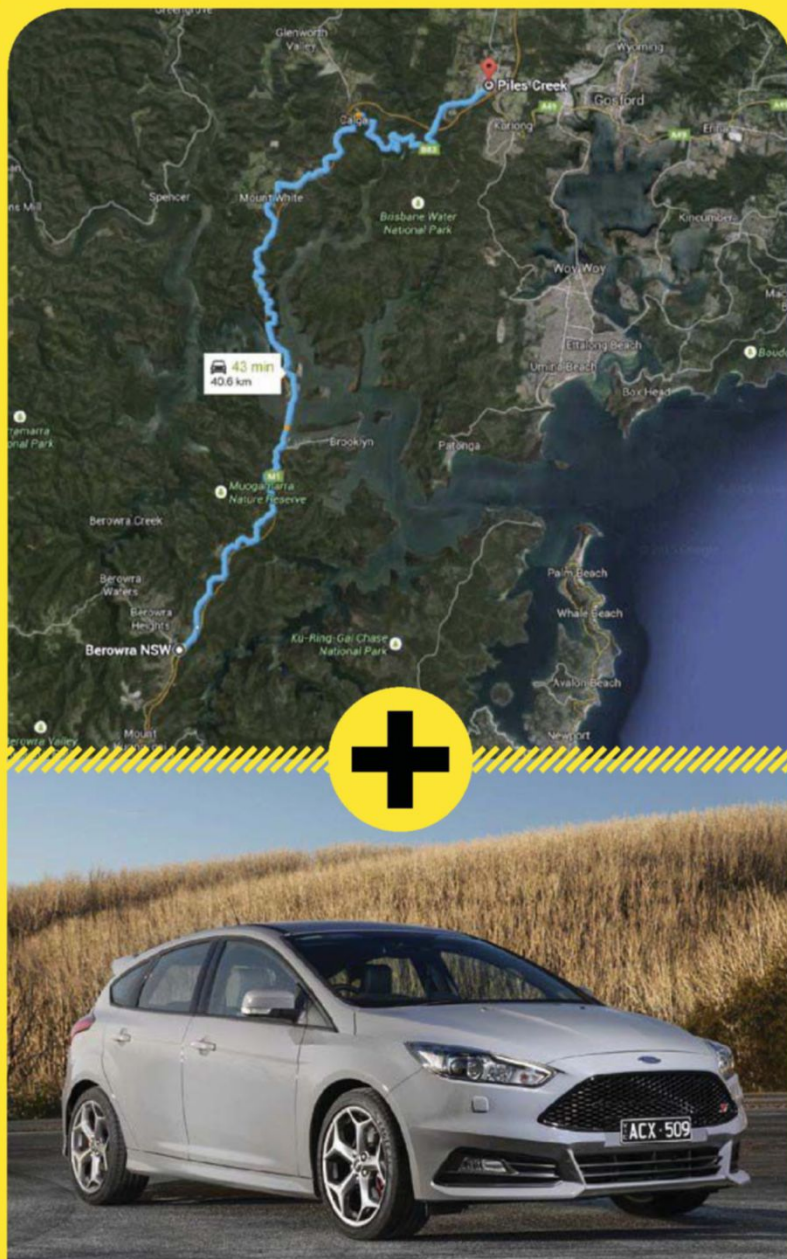
URL: www.ford.com.au

corner on the power would usually see some understeer, but the ST maintains control by applying braking torque to the inside wheel like an electronic limited slip diff. The result is a hot hatch that is perfect for having fun in the hills. The Focus ST only comes in a six-speed manual option, which along with the Recaro bucket seats, gets a solid workout on a twisty road.

The Ford also comes with the Sync 2.0 system that connects to a smartphone and features an 8" screen. Not only does it control the entire infotainment system, it can even phone emergency services and supply a location in the event of an accident. Not that we would ever have an accident thanks to our sensible driving.

We actually hit some of our highest peak G-Forces on the Old Pacific Highway, thanks to the tight corners and road hugging Ford platform. Ford heads who want to push it even further should hang out for the upcoming 235 kW Ford Focus RS.

- ❶ **CAR:** Ford Focus ST
- ❷ **ROAD:** Old Pacific Highway
- ❸ **CORNERS:** Tight
- ❹ **MAX G-FORCES:** 0.51 g



SISTER ROAD WORLDWIDE

Tail of the Dragon

For even more curves, the Deals Gap manages 318 corners in just 18 kilometres. Like the Old Pacific Highway, it winds through the forest, with little sign of civilisation and is very popular with motorcyclists. There is even a "tree of shame" that is covered in parts from numerous crashed motorbikes.



Dangerous Curves



- ❶ **CAR:** Tesla Model S
- ❷ **ROAD:** Royal National Park
- ❸ **CORNERS:** Tight to sweeping
- ❹ **MAX G-FORCE:** 0.41 g

THE ROAD

Just south of Sydney, the Royal National Park is crossed by a fantastic winding road that weaves through the forest. The southern end emerges from the trees with amazing coastal views, before winding down over the sea cliff bridge. Busy on weekends, the road is often almost deserted on weekdays and has a great combination of long sweeping corners to tight hairpins. For those who don't want to stop, continue on the Grand Pacific Drive down past Wollongong, or loop back to Sydney inland via Macquarie Pass.

THE CAR

What better way to enjoy nature than in a silent electric car. The smooth yet firm suspension on the Model S ate up the endless corners, while the brutal electric

acceleration was ideal for powering out of slower tight bends. Driving the Tesla is very different to a normal car, and can be essentially done with one pedal. Pressing on the accelerator sees smooth acceleration, while backing off engages the regenerative braking, topping up the battery. It's only in the odd tight corner that it's necessary to jump on the brakes hard enough to actually engage the

SPECS

Engine: Electric Rear Wheel Drive
Power: 285 kW
Torque: 440 Nm
Range: 481 km
Price: From \$115,000
URL: www.tesla.com.au

mechanical stopping system.

While the drive is a little more taxing on the battery than the cruising about town, we made it back to the Star City Casino with plenty of range to spare.

The Tesla Model S currently available in Australia is the single motor rear wheel drive model, but the dual motor AWD Model S is available for order. It features a combined 568 kW of power, over 500 km of range and can hit 100km/h in just three seconds.



SISTER ROAD WORLDWIDE

Arthur's Pass National Park

Winding through the the New Zealand south island's mountains, the State Highway 73 running through Arthur's Pass has sweeping bends, tight corners and even a curving concrete bridge. Tesla Supercharger access is a little scarce... in fact the closest is actually back in Australia, so make sure you have a friend at the far end with a charger installed in their garage...

Dangerous Curves

THE ROAD

Heading northwest out of Sydney from Windsor, the Putty Road winds for 174 km through national parks all the way to the Hunter Valley. With dramatic mountain views of the Colo River early on, the road becomes an endless series of high speed sweeping corners with little traffic. First opened in 1823 (as Bulga Road), the route was originally popular with cattle rustlers and Bushrangers.

THE CAR

What better way to enjoy a sunny afternoon drive than with a supercharged Jaguar F Type convertible. Having the top down is pretty much mandatory as the magnificent exhaust note bounces off the hills. While opting for the manual might seem like the smart choice, the dual clutch eight-speed automatic with flappy paddle shift is better in almost every way. It shifts fast yet smooth,

letting out a satisfying burble and crack from the exhaust. The auto is actually faster off the line than the manual and offers better fuel economy.

While the infotainment system feels a little dated, the HID Xenon headlamps, flush door handles and automatically deploying rear spoiler help give the car a smarter feel.

The Jag also has a switchable active exhaust, which goes from a muted growl to a thunderous roar.

The Jaguar doesn't feel big or heavy on the road, and is remarkably agile considering the 1614 kg weight. Still, it eats up the big sweeping bends of Putty road, while still being able to throw itself through the very occasional tighter hairpin.

For an even better exhaust note and more performance, opt for the 404 kW supercharged Type R V8 model.

SPECS

Engine: 3 Litre Supercharged V6

Power: 280 kW

Torque: 460 Nm

0-100: 4.9 seconds

Price: From \$188,000

URL: www.jaguar.com.au

1 CAR: Jaguar F-Type S

2 ROAD: Putty Road

3 CORNERS: Sweeping

4 MAX G-FORCE: 0.35 g



SISTER ROAD WORLDWIDE

Black Forest

Sweeping through the German forests and mountains towards the Swiss border, Route 500 is an ideal road to cruise in a powerful car. It's at a high altitude, so rug up in winter, but during the summer a soft top makes taking in the scenery even more relaxing.



HOW TO BE AN

EXP



←
Swung with
unbridled enthusiasm

YOU CAN'T IMAGINE
**WHAT
HAPPENS
NEXT!**
(OR MAYBE YOU CAN.)
EITHER WAY,
GOOGLE IT



IN ANYTHING

with Neil deGrasse Tyson,
expert on everything

Frozen in
liquid nitrogen

Contributors

Josh Dean
Breanna Draxler
Kevin Gray
Lindsey Kratochwill
Lois Parshley
Katie Peek
Erik Sofge
James Vlahos



HOW TO BE AN EXPERT IN ANYTHING

NEIL deGRASSE TYSON

Host of *StarTalk*, director of the Hayden Planetarium



INTERVIEWED BY CLIFF RANSOM

To be an expert means you are on the frontier, making discoveries, thinking thoughts never before dreamed of. I'm an expert in astrophysics.

I don't generally share opinions. It may not feel that way because I speak passionately about what I know, but if you look at my tweets and books, I hardly ever express opinions—because I don't care if you have them. I don't care a rat's ass. As an educator and as a scientist, I care only that you are scientifically literate.

The more informed you are, the more empowered you are to think for yourself, and the more representative our democracy will be.

Don't come to me to debate whether climate change exists. If you're coming to me in that fashion, you do not understand how and why science works. You're expressing an opinion, and I'm expressing a fact.

Successful people are driven without regard to their social life, love life, the opinions of others. Every one of them has a story saying, "Here's a list of people who said I should do something safe."

To be genius is to be misunderstood, but to be misunderstood is not necessarily to be genius.

I am the consequence of my life experience. Everything that has happened to me has summed to be what I am. If I jumped back in time, I would derail that learning curve, so I don't have any urge to go to my younger self and say, "Do this, not that." What would that mean? Making mistakes contributes to your wisdom.

It's not that we fear technology, it's that we occasionally take it for granted, and when we do, we discount the brilliance and work that went into it. You'll say, "Oh, we don't need to increase the funding on science; I've got my smartphone. We don't need to go into space; I've got *weather.com*." Well, where the hell do you think you got the image of the hurricane that just tore up Galveston, Texas?

If you want a career in science and technology, well, you better hang out with some geeks. Go ahead. They are a friendly people. They're not talking about the clothing you are wearing. They're not talking about your waistline. It's just, "Who are you, and do you have interesting things to say?"

No matter what you do, you need to be able to fail and know how to recover from it in order to one day succeed. There is no successful person who has never failed. Think of the lessons you learn every time you fail. It's the people who ignore those lessons who basically check out of that contest permanently.

The fastest way to end a career in science and technology is if you're guilty of fraud. No one will listen to anything you publish thereafter. The greatest statement you can make to a scientist is to pay no attention to his or her science.

When you are first in the world to know something, there's nothing like it. There is no salary, there's no car you can drive to substitute for that feeling.

ONE OF MY FAVORITE LINES

COMES FROM POET
RAINER MARIA
RILKE: "BE PATIENT
TOWARD ALL THAT
IS UNSOLVED IN
YOUR HEART AND
TRY TO LOVE THE
QUESTIONS
THEMSELVES."



How to Build a YouTube Empire

FELICIA DAY, GAMER AND FOUNDER OF GEEK & SUNDRY CHANNEL

My name is Felicia Day, and I make Internet content. I guess that's the easiest way to put it. When I was 6 years old, my parents had a CompuServe account, which was one of the earliest commercial dial-up services. So my whole life I've been raised with the idea that you could connect with people online. When I took that first venture into filmmaking and saw people respond to it, I couldn't stop making videos no matter what barrier was in my way.

It was two years after YouTube's beta launch when I started uploading episodes of *The Guild*. It was a passion project about the world of gaming. We were crowdfunded before anyone even knew that was a thing. As a whim, I put up an ad on our website, and people gave us enough money to shoot again. We eventually started a company called Geek & Sundry, which makes dozens of Web series. A year ago, we sold the company to Legendary Entertainment, so now we're expanding to other platforms, such as Twitch, our own website, even television.

Honestly, were *The Guild* not successful, I still would have done it. That's the lesson I want to convey. We all have a unique perspective on life. If you look at the people who changed history, none of them tried to be like everybody else. Those peaks and valleys, the things that make you different, those are the things you should play into. The great thing about the Internet is that it's there to help you grow your weirdness. That's the way you're going to be exceptional in this world and get your voice heard—not by tamping it down.

How to Go the Distance

Nate Ballou, 95
America's
oldest practicing nuclear
chemist

Whatever your situation, make long-term goals and keep them in mind as the years pass, but also be open to all of life's opportunities. I've always been pretty focused on my research. I never felt distracted by extraneous things. But balance is important too. My wife and I have been married for 41 years. We landscape a lot. We also devote a couple of weeks to travel every year. Maybe that balance didn't help directly with my science, but it helped me to be a better person and therefore probably more effective in my science too.

“**YOU CAN'T TRY TO COPY SOMEONE'S SUCCESS. YOU HAVE TO BE TRUE TO YOUR WEIRDNESS.**”



HOW TO BIRTH THE NEXT SCIENTIFIC REVOLUTION

JENNIFER DOUDNA

Co-creator of gene-editing technique CRISPR, which allows scientists to repair disease-causing genetic mutations

I grew up in Hawaii and I had a great chemistry teacher in 10th grade, Ms. Wong. And Ms. Wong was very good at showing kids that science is not about memorizing facts in a textbook. It's about figuring stuff out. If you have a question, you can design an experiment to answer it. I found that really exciting. Experimental science is 90 percent about the things that don't work the way you think they will. It's being persistent in the face of facts. It's looking for connections others don't see. It's important to foster these skills in yourself if you want to do this job. You also need to work with fun, smart people. Science doesn't happen in a vacuum. In a lab, other people's enthusiasm and ideas inspire you. You might be stuck, trying to figure out “How do I do this experiment?” or “I don't understand the results I'm getting. What does it mean?” It's helpful to hear, “Oh, did you think about this?”

WHY DIY MATTERS

LIMOR FRIED

Founder of electronics-hobbyist company Adafruit

INTERVIEWED BY SOPHIE BUSHWICK



When I was about 7 or 8, I saw a bunch of balloons stuck to the ceiling at a local mall. No one could reach them, so I went home and constructed a mechanical arm. It was then, after going back and retrieving all the balloons, that I realised engineering was for me.

I decided early on that it's only work if you'd rather be doing something else. I really didn't want to wake up early and go to an office with a bunch of people telling me what to do. So I started selling the kits I made with a simple PayPal button on a website I built.

You can create a good business and a good cause, but only if you're willing and able to contribute something. For instance, I publish hundreds of free open-source repositories that help people make their electronics dreams come true. They also become customers. They become contributors. By making and sharing open-source hardware and software, we're putting value back into the system.

Tinkering, building, and sharing make a lot of great connections for people. There are tons of friends I've met because we were both tinkering on something and we found each other. I like bringing together as many different people as possible, solving interesting problems, and using technology to make the world a better place.

A DIY project teaches something more important than a skill like soldering or coding—it teaches problem solving. With electronics, you might need to rethink assumptions on how something physically works, or some code that needs rewriting. It's more than physical. It's more than digital.

Purchasing something isn't the same as making something—you have a more intimate relationship when you make something and share it. The physical things don't matter as much as the experience and the time you spend learning something or sharing that time with others.

My advice for aspiring DIYers who love tinkering but know nothing about electronics: Pick up an Arduino or Raspberry Pi and dive in—we have about 800 tutorials to get you started.

I don't really take vacations, but I do take days off. On Sunday, I took the day off and made a cellphone and GPS data logger that publishes my location to a new service we're working on called adafruit.io. I rode my bike 10 or so miles, and it worked out great. This week, I'll send the files off to the PCB (printed circuit board) house, and soon this will be a new product.

If I want to motivate a teenager to put down a smartphone and create something, I usually ask what's annoying to them. And they'll say that their parents or friends watch TV shows they don't like. So I'll suggest they build a TV-B-Gone kit—it's a fun and mostly harmless kit that, once built, turns off TVs. Nothing motivates a teenager like mischief.

People ask why I chose this hair color. It's apex predator pink. It chose me.

**IF YOU WANT TO
CREATE SOMETHING
AMAZING**

THERE ARE
PEOPLE OUT
THERE TO HELP
YOU. WE'RE ALL
INTERCONNECTED,
VIA THE INTERNET.
WE'RE NOT SOLO
ACTS ISOLATED IN
WORKSHOPS.





HOW TO CREATE YOUR FRIENDS

HEATHER KNIGHT

Social Robotist



I started building robots. Then I fell in love with them. At Carnegie Mellon University, I'm working with robot body language. People usually think of companion robots as ones that are just hanging out with you, as your friends or toys. I think they're essential for enabling the next generation of robotic machines. We want them to fit into our world, not for us to have to redesign ourselves.

Of all the classes I took in high school, the one that I think was most akin to creating robots was art. If you're making a sculpture, you come up with an idea and build it. If it falls over, you need to reconsider your construction. Like art, engineering is the process of thinking about something that hasn't existed before and building it. It's very creative. But social robotics is also rooted in human psychology. You have to make something that people can understand.

The emphasis on creativity will bring in more diversity. It's not just the diversity of gender and race. It's like revisiting the stereotypes of what being an engineer is to begin with. I was at the Three Rivers Arts Festival, and I gave a talk. A woman came up afterward and said: "I really have to tell my daughter about you. She's into ballet and art. And I'd love for her to be more into engineering, like you." Well, those don't necessarily have to contradict. Why can't she do them both together?

How to Motivate a Nation

Megan Smith
United States
Chief
Technology
Officer

For almost every problem we have in the world, there are people on this planet who have an idea, or a pilot, or a working solution. It is my job to discover and support them. Unfortunately, the country's talent networks are often divided geographically or racially. There's a bunch of underrepresented people in tech and innovation, often women and people of colour. Yet, you can find extraordinary people if you look. The disaster-response community holds hackathons, where they do things like figure out how to use a car to charge cellphones. That's creative!

“**YOU DON'T NEED TO BE A NERD TO BE AN ENGINEER. YOU DO, KIND OF, BUT YOU DON'T.**”



HOW TO (LITERALLY) BREAK INTO CODING

JAMES GOSLING

Father of the Java programming language

POPULAR SCIENCE: When did you start writing code?

JAMES GOSLING: When I was 13, we lived about 5 km from a university, and my dad's friend brought me to see the computer-science department. I was entranced. I just had to go back. But I was a long way from going to college. So instead, I got good at watching people punch the keys to the security doors. I literally started breaking in.

PS: What did you do there?

JG: I was big enough that I was plausibly a university student, and I befriended a fellow who was working for the physics department. The department needed somebody to write software for PDP-8. I had already been teaching myself to program on it. So I ended up getting my first paying software job at 14 as a code monkey for a bunch of scientists trying to figure out how the aurora borealis works, which was so mind-explodingly fun.

PS: What about that other education you were supposed to be getting?

JG: High school was kind of a dubious thing for me. I ended up skipping a lot of classes. This was in the '60s, and there were a lot of drugs around; kids missed lots of school. But my teachers figured out what I was doing and covered for me.

PS: You later created Java at Sun Microsystems. Did you think it would take off?

JG: No. It was more like writing a science-fiction novel. But now there are some 10 million professional software engineers who use Java, and many more people know how to use it. It's even what the Advanced Placement computer-science course in high school is based on, which my kids study and get very grumpy at me about.



How to Face Fear

**LINDSEY HALLEN, HOSPITAL NURSE
EBOLA RESPONDER**

I work in an emergency room in New York City, and every day during the outbreak, we'd debrief about what to do if someone came in with Ebola. You could select if you wanted to work those patients. So I started thinking about it, and it became so obvious to me that help was needed in West Africa. So I decided to go.

I never second-guessed myself. I try to deal with fear in the most rational way possible. With the fear of getting sick, I made an educated decision that it was a risk worth taking.

In the hot zone, there was a young guy hooked up to an IV, and I had a short conversation with him through an interpreter. When we went back three hours later, I couldn't find him. I was about to leave when I realized he was lying under the bed. He was no longer alive. It looked like he had had a seizure. He was lying in a contorted position on the concrete floor. Even saying this to you...it's hard to process. It's just unacceptable that someone would have to go through that. It could have been prevented with the right resources.

The hardest part is wanting to provide so much more care. But we helped and it was important to go. Everyone has a thousand dreams, or thinks "Oh, it would be great if I could do that." No one is going to tell you to do something. I had to seek it out. I encourage people to do things others perceive as risky. If everyone had the courage to take chances, so many great things would come from it.

←
Lindsey Hallen, Sierra Leone, March 2015

How to Market Greatness

Peter Thiel
Entrepreneur,
co-founder of
PayPal,
partner in
venture
capital firm
Founders Fund

I think great scientists and great inventors would do well to partner with great business people. One of the challenges scientists face is that they think the science is enough to carry the day. You come up with a breakthrough or an invention, and you think the world is going to beat a path to your door and beg to adopt it. Actually, it's always a challenge to turn even a great invention into something that consumers, or other businesses, will buy and use.



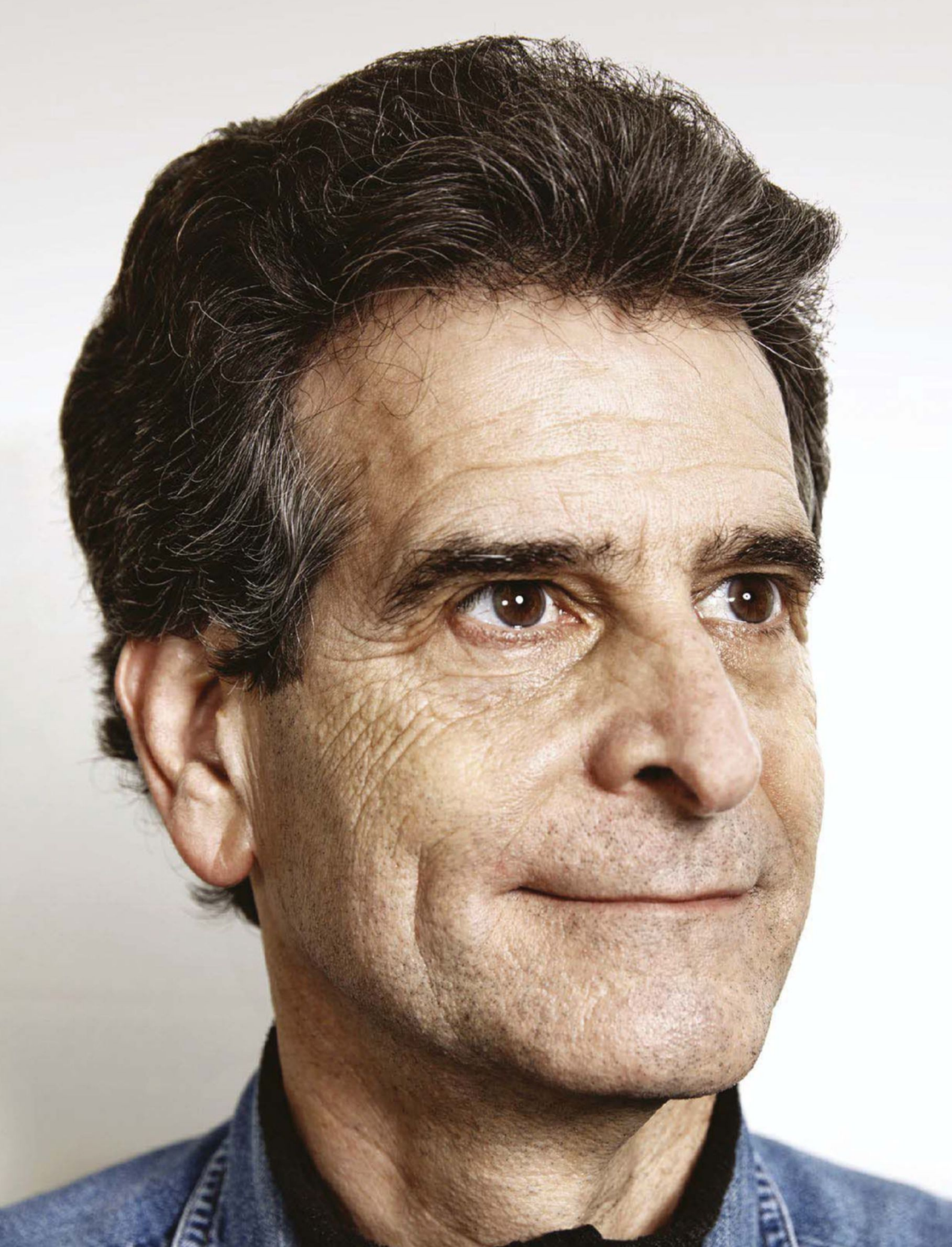
HOW TO PIONEER A NEW FIELD

WILLIAM BORUCKI

Former head of the *Kepler* exoplanet-finding mission; as of July, *Kepler* had identified 4,661 candidate exoplanets

I applied to just one place out of college, and that was NASA. I had always been interested in space exploration from reading science fiction when I was young. Many scientists and engineers at NASA read science fiction as kids, and that sort of opened up their imaginations to all sorts of possibilities. I knew that finding habitable planets would be an important first step in exploration. So I built an instrument that would allow us to search for them. Then I convinced NASA that we should fly a space mission with it on board. Funding for the research came through in 1983, but *Kepler* didn't launch until 2009. That's, I don't know, nearly 30 years. It takes a long time, but if you've got something you think is extremely valuable, extremely important, you should be willing to persevere. Sure, I felt frustrated, because year after year the answer was no. But I knew it would someday fly and be very, very important to NASA and to mankind.

“
**I THOUGHT:
DO NOT BE
AFRAID. THIS
IS GOING TO BE
LIFE-CHANGING.**



WHY GEEKS SHALL INHERIT THE EARTH

DEAN KAMEN

Inventor and entrepreneur, founder of FIRST Robotics Competition

INTERVIEWED BY JENNIFER BOGO



People used to say to me, I can't believe you quit school and risked everything to start a company. And I answer them: I risked everything I had because I had nothing.

Very early in my teens I decided to educate myself. I realized I was never going to be a very good student because I didn't like teachers judging me by what I thought were arbitrary standards. I decided I'd let the world judge me by whether I could do something of value—solve a problem or build something. And if people wanted it, they'd pay for it. And that's when I decided I'd be an inventor and entrepreneur.

I'd rather fail at trying to do something really big than succeed at being mediocre.

Start inventing as early as you can because, compared with most things, it's more likely to take you to places you can't predict and that you can't schedule and you can't budget for. Do all that when you can tolerate the insecurity.

Kids are full of imagination and much more willing to fail. Just watch a 3-year-old. They poke everything, and if it hurts they don't poke it again. They learn how to stand up and walk and talk, all at a breathtaking rate. Try to teach an adult a foreign language.

School frequently isn't testing whether you understand something but whether you're familiar with it. What's Newton's second law? You say $F=ma$, and you get an A. That does not reflect a deep understanding of Newtonian mechanics, or electrodynamics if it's Maxwell's equations, or thermodynamics if it's the first or second law. That the integral of dQ over T is entropy is a nontrivial thing to understand.

FIRST is an unabashed success: about 40,000 teams, in 80 countries, competing in engineering contests, including an extremely popular robot-building challenge. It has 125,000 volunteers and 3,500 corporate sponsors. Everybody is hugely proud of it. But by the standards of our culture, compared with the Super Bowl or a big rock concert, I'm dismally disappointed. I always believe that by next year it'll be so obvious what a great thing this is that it will be available to every kid on the planet.

The Bible said the meek shall inherit the earth; I personally think it's the geek who shall inherit the earth.

We should embrace all those people who don't get geeks and make them part of our culture. Because a world that has only a few geeks, and those geeks are not leading the rest of the world in the right direction, is going to be an ugly world.

I would say to all these kids, "Keep it up, and although it's tough work and sometimes you fail, and sometimes people might take shots at you when you do fail, don't let it bother you."

If you're lucky enough to understand and appreciate tech, you've got to spread that wealth. You've got to get more kids capable of being part of a future in which the world will be prepared to solve its ever more complex problems. 

WHEN'S THE RIGHT AGE TO BECOME AN INVENTOR?

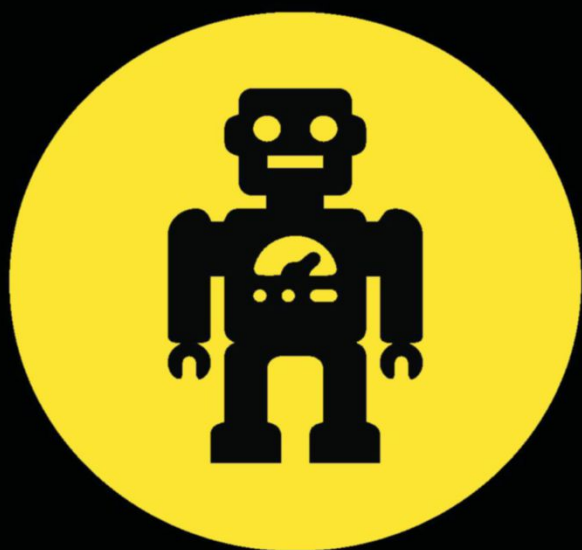
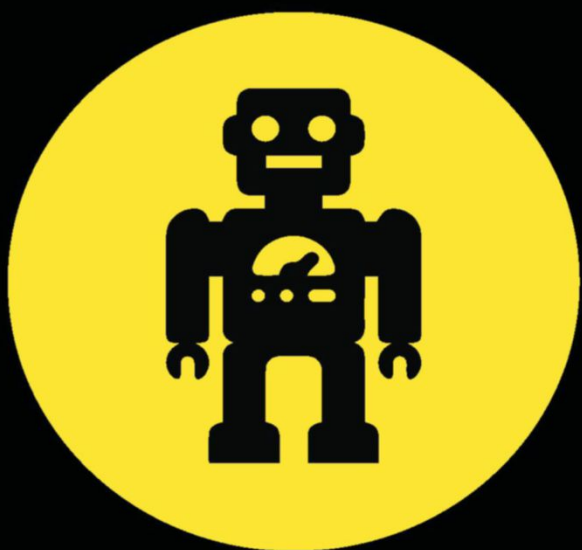
I'D SAY IN THE WOMB. SERIOUSLY, KIDS DON'T HAVE BRED-IN ANXIETIES ABOUT TRYING TO AVOID FAILURE. THE YOUNGER, THE BETTER.

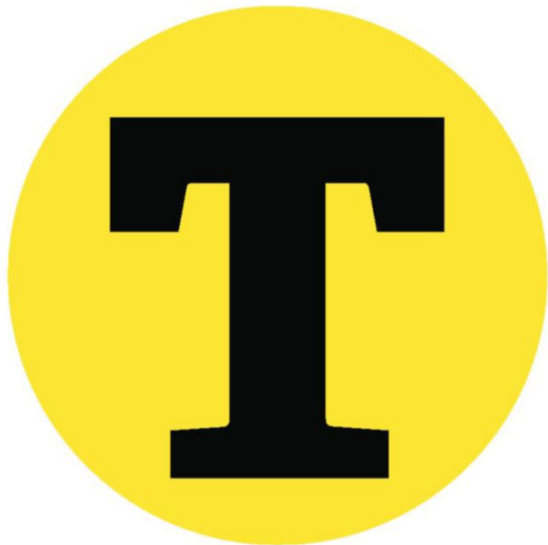


Uber Powerful

The car-service startup has a brazen plan to become a robotic superpower. Should we be excited or afraid?

BY ERIK SOFGE





Earlier this year, two engineers huddled behind computer monitors as they fine-tuned a robotic ape. The 200-kilogram simian-inspired machine, called Chimp, would soon be competing in the Pentagon-funded DARPA Robotics Challenge. The competition to build disaster-response robots, which had started three years before, was nearing its final showdown. And Carnegie Mellon University's Chimp was considered a front-runner for the top prize of \$2 million.

But as Chimp went through its paces, the rest of the robots in the university's cavernous National Robotics Engineering Centre sat unattended. The centre was typically a flurry of activity, with engineers hunched over terminals tethered to all manner of autonomous machines, including mowers, harvesters, excavators, and combat vehicles. Now, in the middle of a weekday, the lab—part of the biggest robotics program in the country—seemed abandoned. It looked more like a museum closed for renovations.

What happened to NREC? In a word: Uber. The San Francisco-based firm is an exemplar of Silicon Valley success, having reportedly raised \$2.8 billion in funding on the strength of a single car-service app. Now Uber is racing to build self-driving cars. No longer content to take on traditional taxi companies, Uber hopes to use robots to lower fares, and ultimately compete with the entire automotive industry. "When there's no other dude in the car," Uber CEO Travis Kalanick said at the Code Conference in 2014, referring to the service's human drivers, "the cost of taking an Uber anywhere becomes cheaper than owning a vehicle...and then car ownership goes away."

This past February, the company announced a strategic partnership with Carnegie Mellon University (CMU) to develop the vehicles at the new Uber Advanced Technologies Centre in

1.



2.



Pittsburgh, temporarily located just a short stroll from NREC. Not announced was how Uber staffed up its centre: by quietly siphoning personnel away from its partner. (Neither Uber nor CMU would comment on this.) By the time we visited, the startup had hired 40 or 50 of NREC's roughly 150 researchers, including Tony Stentz, the roboticist who had served as the centre's associate director for 13 years and director for nearly five.

"Uber was incredibly smart in that it went to the one place, outside Google, that has all of the right people—people who actually have a shot at tackling autonomous driving," says Boris Sofman, who studied robotics at CMU and had Stentz as an adviser. Like many CMU grads, Sofman went on to found his own startup, Anki, which makes autonomous toy cars.

Carnegie Mellon has long been a leader in robotics. It was the first university to offer a doctoral program in the discipline. Its contracts to commercialize robotic technologies at NREC routinely pull in an estimated \$20 million annually. And its researchers pioneered robotic cars, winning the DARPA Urban Challenge with a driverless Chevy Tahoe in 2007. When Google started its self-driving-car program, it dipped into CMU too. "It's not because we're good; it's not because we're smart," says William "Red" Whittaker, director of CMU's Field Robotics Centre. "It's because, my God, we started so early, and we were so strategic, and we built an army."

But when a third of your army decamps in the night, including its colonels, questions are inevitable. The most important one is this: What does the plunder of a leading research institute mean for the future of robotics?

Like most scientific pursuits, robotics thrives on collaboration across teams and projects. But as the field enters a new era of funding and interest, many of its most talented engineers are being cloistered out of sight. Amazon and Apple have been amassing in-house robotics teams, and keeping their work largely under wraps. Uber has asked its new hires to sign nondisclosure agreements. And when Google acquired eight promising robotics firms in late 2013, those companies immediately stopped discussing their research. One of those acquisitions, a Japanese startup called SCHAFT, built a humanoid S-One robot that dominated the first phase of the DARPA Robotics Challenge. Google pulled SCHAFT from the competition in early 2014, and S-One hasn't been seen since.

Until Silicon Valley starts churning out actual robots, some think its newfound interest could hinder progress in the field. "I've been party to conversations in the upper crust of the research world," Whittaker says. "The language that's been used is the threat of a research drought. This vast, amazing talent is picked off in such a way that it takes a guy like me 10 years to make them, and an instant for them to disappear."

Rich Mahoney, director of robotics at SRI International and president of the Silicon Valley Robotics industry group, argues that innovation is being



3.



1. Carnegie Mellon's Chimp uses machine perception to navigate its environment—just as an autonomous car might.

2. A few months after Uber opened its Advanced Technologies Centre in Pittsburgh, a research vehicle was seen roaming the city's streets.

3. Uber's CEO, Travis Kalanick, said that cutting out human drivers will make his service cheaper than owning a vehicle.

smothered in the private sector. "There are hundreds, literally hundreds, of roboticists in Silicon Valley—extremely talented people—who are not engaged in the robotics community," he says.

The newly cash-infused state of robotics has been compared to the early days of computing. Scrappy startups like Apple and Microsoft innovated themselves into positions to rival established players such as HP and IBM. What's changed is that now firms like Google and Uber are pre-empting the development of a thriving startup scene by sucking up roboticists in large numbers. "Who are the visionary early-stage leaders?" Mahoney asks. "Who's the Bill Gates and Steve Jobs of robotics? These companies have so many resources available that they can just go out and hire a block of talent. If they align that talent with the right products, they can do something really special. If they don't, they're just taking these players out of the market."

While it would be easy to view CMU's loss of talent as a casualty of Silicon Valley's rapacious self-interest, most roboticists see it as affirmation. "There's a brain drain from academia to industry right now," says Vijay Kumar, a roboticist at the University of Pennsylvania and former director of the school's GRASP Laboratory. "But if the direction of the brain drain were the other way, that means we're in the wrong field."

Earlier this year, Qualcomm Technologies acquired KMeL Robotics, a startup spun out of GRASP Lab in 2011 that specializes in autonomous drones. Though the terms of the deal haven't been disclosed, Kumar described the payout as "an ungodly amount of money." Qualcomm is also spending \$1 million on a four-month robotics accelerator program that culminates this fall. "I love the attention that the field is getting," Kumar says. "I love that my colleagues and my students are being attracted by the Googles and the Qualcomms and the Ubers. The more interest that industry shows in the field, the more people will realize that to make a complete product, you need more basic research investment."

There's no question that the private sector can free roboticists up to do more, quicker. "The average professor will spend 50 percent of their time just writing grant proposals, trying to justify the research they want to do," says Anki's Sofman. Despite the promise of the DARPA Urban Challenge, it wasn't until Google hired roboticists and started field-testing autonomous cars that robot vehicles gained real momentum. Academia may have given birth to self-

driving cars, but it was a corporation that set them loose in Bay Area traffic.

"It's insufficient to just write research papers," says Sebastian Thrun, a professor at Stanford University's Artificial Intelligence Laboratory and founder of Google's self-driving-car project. "At the end of the day, these products need to be built and brought to market to be impactful." Thrun is perhaps more familiar with this issue than any roboticist, having worked as an associate professor at CMU before joining Stanford in 2003, and then switching to a full-time position at Google from 2011 to 2014. Though the scale of Uber's recruiting drive surprised him, Thrun isn't concerned by it at all. "I think it's a sign of confidence, that the age of robotics has begun."

Most in the field share Thrun's opinion: that robotics has reached an inflection point. In addition to the recent headhunting and spate of acquisitions, venture capital has been flowing into the small outfits that haven't yet been scooped up. Firms invested an estimated \$341 million in robotics in

2014 alone. That's tiny compared with other tech sectors, but it's up from 2013 by more than a third.

As of press time, Uber still had job openings for 24 different types of engineers at its Pittsburgh research centre. And a vehicle testing systems for its future self-driving car had already been seen on city streets. NREC, meanwhile, isn't in what *The Wall Street Journal* called "a crisis."

The lab is hiring to fill vacant slots and actually expanding, adding new positions and seeking new contracts. Silicon Valley will be back and, like other universities with acclaimed robotics programs, CMU has to view its inevitable future personnel losses as victories for the field.

"The only metric of a technology is the extent to which it gets out there in the real world, impacts life, and generates wealth," Whittaker says. "I haven't spent a lifetime creating this stuff for it to gather dust in a basement." 



"UBER WENT TO THE ONE PLACE, OUTSIDE GOOGLE, THAT HAS ALL OF THE PEOPLE WITH A SHOT AT TACKLING AUTONOMOUS DRIVING."

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AN UP BOX 3D PRINTER!

We love 3D printers

here at Australian Popular Science, but until now most models have either been really small, or hardcore DIY kits. The UP Box is one of the first really big,

fully-enclosed desktop 3D printers. It has a massive 10 litre build platform, an HEPA filter and fan to kill those burning-plastic smells, and a build speed up to 30% faster than

some of its competitors. Plus, hardware buttons on the side that let you pause printing, cancel print jobs, or just turn on the interior LED lights to see how your creation is going! Coupled with a new version of UP's versatile and straightforward printing software, the UP Box

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GO HACK YOURSELF*

*FIGURATIVELY

**TIRED OF THE
MERE HUMAN
ABILITIES OF THE
BODY YOU HAVE?
CONSIDER A FEW
AFTERMARKET
OPTIONS.**

Gamers often perform repetitive tasks to improve their character's skill set, gain rewards, and advance to new levels. The process is known as grinding: Now, an underground movement has taken up that expression, calling themselves grinders, and they're trying to gain some of those same superskills—only in real life, and by hacking their bodies. To cynics, the upgraded-self movement—aka body hacking—can seem a reckless and narcissistic pursuit. After all, treating your body like a home science kit can have serious consequences (scarring, bleeding, pain on the scale of passing out). Yet tinkering with human hardware is a centuries-old pursuit. Bolting titanium plates onto problematic spines has become downright common. Today's transhumanists take it further. They seek to extend the senses and co-mingle them, allowing themselves to do things like detect Wi-Fi, hear colours, sense magnetic north, and see in the dark. Technology is driving the trend. But so are a few renegade surgeons—operating in an ethical gray area—and a growing number of innovative grinders, all of them hoping to one day push the cyborg off the Comic-Con floor and out onto Main Street.

BY **BOB PARKS** | ILLUSTRATIONS BY **MUTI**



TOUCH ELECTROMAGNETIC FIELDS

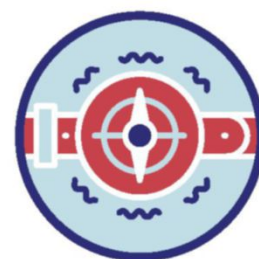
Magnets are easy to install and among the first hacks grinders try. Piercing-shop staffers typically embed a barrel-shaped neodymium magnet, the size of a grain of rice, beneath the skin of a finger. The magnets are coated in bio-proof materials such as titanium nitride (used to coat replacement hips), silicone, and Teflon. When the grinder encounters an electromagnetic field, it vibrates against the nerves, enabling the user to feel things, like power transformers and microwave ovens. They're also good bar tricks: Dangle paper clips from your finger! But use with caution. One grinder injured the tissue near his implant—by opening a pickle jar.

WARNING: In case we weren't clear, please don't try these hacks at home.



Hear Distance

Want to sense distance like a dolphin? Bottlenose—from the hacker collective Grindhouse Wetware—creates sonar perception in an off-the-shelf kit (\$60). Its dolphin-like range finder locates an object in a dark room using an ultrasonic distance sensor. It then sends electromagnetic pulses to a magnet in the user's finger, providing a sense of things like an object's size and distance. As a user moves closer to the object, the sensations grow stronger. Bottlenose can also detect radiation or the presence of ethanol, and it can pick up Bluetooth signals. A thermal infrared sensor spots warm objects—such as a stove or a clothes dryer—from a couple of metres away. There are also add-on sensors for detecting things like ultraviolet light and for sensing compass headings. For people without magnet implants, a wearable magnet works just as well, delivering the same sensory vibrations outside the skin, as long as the magnet is worn within the range of the Bottlenose device.



Feel Direction

We humans get lost, and finding our way usually means asking directions. For a 2014 report in the journal *Consciousness and Cognition*, researchers at the University of Osnabrück in Germany wanted to know if they could instead create a learned sense of direction. For seven weeks, nine male and four female subjects wore belts with 30 vibrating motors stitched onto an elastic fabric that indicated when they were facing magnetic north. The subjects biked and walked regularly. Over time, they improved their overall orientation abilities on a subcognitive level. "Today I stepped out of the train, and I immediately knew where I [had] to go," subject BWP9 said. "With the belt, one does not have to always care so much whether there is a turn ... one simply feels it!" Once the belts were removed, however, some users felt disoriented and insecure. Similar devices are available as kits, such as the North Paw from sensebridge.com or as free plans on instructables.com.



SEE THROUGH DARKNESS

The deepsea dragonfish, found in oceans of the Southern Hemisphere, swims 1600 m below the water's surface. A chlorophyll derivative in its eyes helps it see in the dark—or rather in a red light cast by a bioluminescent organ. In March 2015, California biohackers Gabriel Licina and Jeffrey Tibbetts wanted to try a similar derivative, Chlorin e6. They bought 100 milligrams from a medical supplier for \$39. A heavy dose would have burned the eyes, so they diluted half in insulin and saline, adding the organic solvent dimethyl sulfoxide. Tibbetts pinned Licina's eyelids with specula and dosed the eyes. After two hours, Licina was able to identify people 20 metres away in a darkened area 100 per cent of the time, while four control subjects had a 33 per cent success rate. So far, there have been no bad side effects.

Meet the Borgs

In 1998, UK professor Kevin Warwick became the first person to have a transponder chip implanted under his skin, but only after receiving ethical approval to experiment on himself and enlisting a doctor to assist him. It wasn't until Seattle-based IT consultant Amal Graafstra had a chip implanted in each hand, in 2005, without seeking approval, that the grinder world found a spark. Graafstra uses the chips to open his home and car doors and to log on to his computer. He also sells them to grinders on his website *Dangerous Things*. Last year, Graafstra became the first to implant a tiny photovoltaic panel in his forearm to learn how much light traveled through the skin and whether it could power internal sensors such as a heart monitor. Though it generated a mere 50 microamps at 3 volts—about a 400th of the current needed to run an LED—he felt elated, saying, “it proves the value of citizen science.”



Hear Wi-Fi

Imagine walking down the street, and instead of looking for that little Wi-Fi sticker on the doors of coffee shops, you could hear a hotspot's presence. London journalist Frank Swain is partially deaf. He wears Starkey Halo hearing aids that link via Bluetooth to his smartphone. Last year, a sound-engineer friend hacked his phone's software, so now it sends melodies and Geiger-counter-like clicks to his hearing aids when it detects Wi-Fi zones. “I pick up a lot more data than you might think,” Swain says. “Routers give away a lot through the pitch of their digital signals, including the brand, the type of router, the Internet Service Provider, whether high security or low security. I can even home in on their location using stereo.”



Turn Fingers into Flash Drives

Computer-readable ID chips are now so small—a mere 3 mm to 6 mm long—that they can be inserted beneath the skin with the aid of a large needle. This is another simple gateway hack for grinders. Like magnets, the chips are typically implanted at piercing shops, without anesthesia, which generally requires a permit to administer. Using Radio Frequency Identification (RFID) and Near Field Communication (NFC), you can make chips operate dozens of consumer devices, such as RFID door locks. You can store data on them and transfer things like video-access codes to a friend's NFC-enabled Android smartphone—all with the simple wave of your hand.



Hear Colour

Colour-blind artist and musician Neil Harbisson saw the world in greyscale for the first 21 years of his life. Then, on December 2, 2013, in a Barcelona clinic, a surgeon (operating without ethical approval) drilled four holes into the occipital bone at the base of Neil's skull and anchored a camera. Its flexible lens arcs over Harbisson's head to just above his brow, where it captures the colour of any object Harbisson is looking at; a chip inside his skull transposes the colour into a frequency (red becomes the musical note F; rose becomes E); and then turns each frequency into a vibration picked up by Harbisson's inner ear. A yellow sock sounds like the G note above middle C; the blue eyes of Nicole Kidman (whom he once met) sound like B. Volume relies on colour saturation. Fused to his body, the camera stalk feels like a long tooth, Harbisson says. Every few months, he has to charge a small battery to power the processor, camera, actuator, and wireless systems. There is no on/off button.



Shock Your Brain into Working Better

Electricity shot into the brain temporarily boosts intelligence, according to academic studies and, less convincingly, to adventurous amateurs. A 2015 analysis in *Restorative Neurology and Neuroscience* surveyed 13 studies that showed improved brain performance through transcranial direct current stimulation (tDCS) and random noise stimulation. The experiments used a very low current of up to 2.5 milliamps (usually corresponding to a maximum 18.5 volts) for no more than 20 minutes. Subjects then completed tasks in which they showed better memory, cognitive control, and math skills. Such experiments are typically done with research-grade equipment in a lab, not performed by amateurs. But with a great deal of risk, grinders have made their own tDCS devices. Some buy them ready-made online for as little as \$150. Either way, of all the questionable biohacks, definitely do not try this one at home.



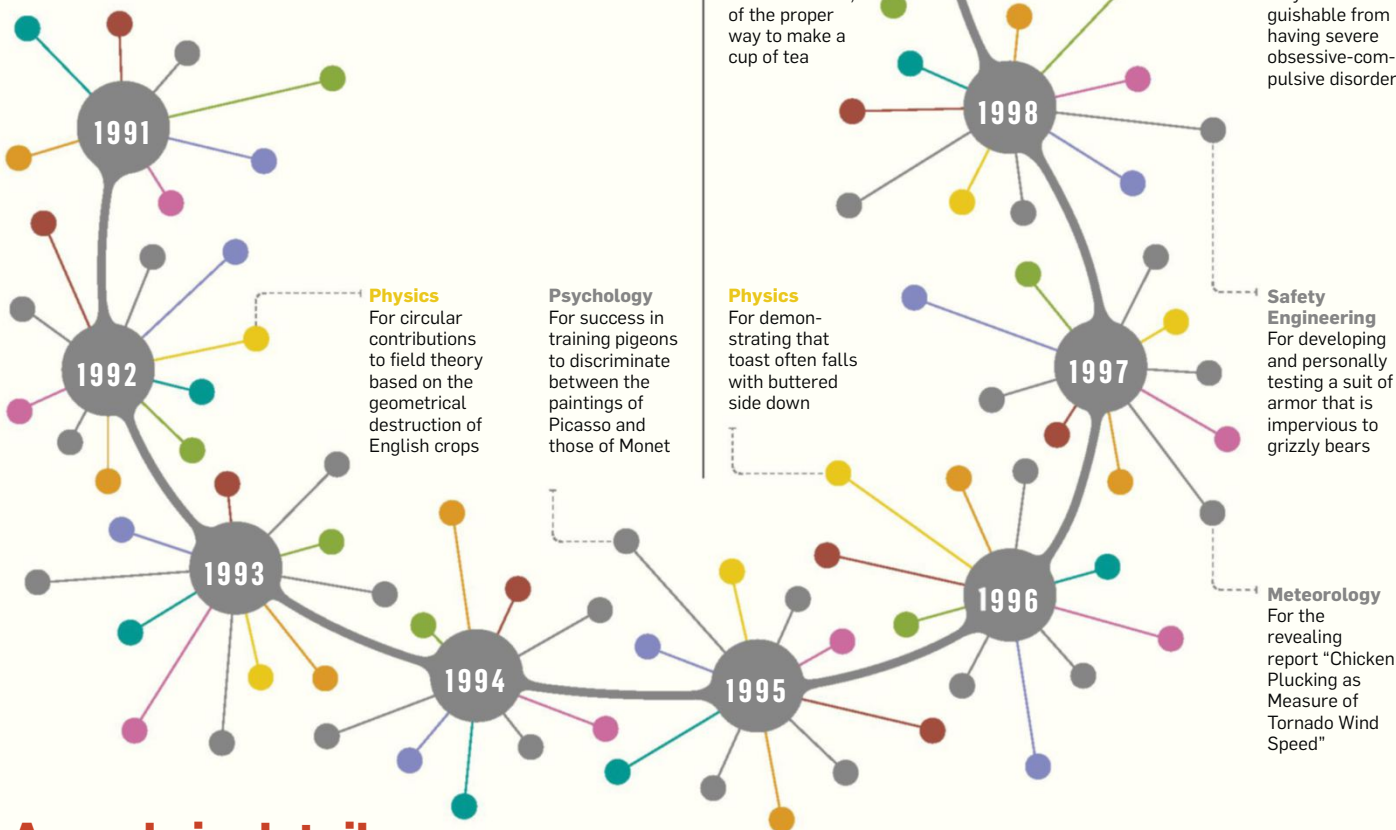
IMPLANT HEADPHONES

Rich Lee, a salesman and grinder from St. George, Utah, wanted true wireless headphones. So he implanted a magnet in the small prominence (known as the tragus) in front of each ear. He then hacked his smartphone to send audio into a signal amplifier that relays it to a wired "antenna" necklace around his neck. The necklace creates an electromagnetic field around Lee's head. And the field induces vibrations in the ear magnets that Lee hears as music. "The sound quality is decent, maybe comparable to a cheap set of ear buds," Lee says. In one experiment, he connected the necklace to a small microphone attached to his heel, which senses subtle tremors in the ground. "I could detect a jogger coming up behind me on a paved road long before I could even see him," he says.

The Less-Noble Nobels

An annual tribute to science's funniest research celebrates its 25th year

In 1990, as editor of a science magazine, Marc Abrahams covered plenty of important research. He also saw lots of science that was just plain hilarious—but those researchers remained obscure. “So,” he says, “we began to celebrate them.” He held the first Ig Nobel awards in September 1991. In the decades since, the ceremony has honoured research that probes why woodpeckers don’t get headaches, and whether humans swim faster in syrup or water (it’s a wash). It’s work that lives up to the Ig Nobel tagline: “Research that makes people laugh and then think.”



Awards in detail

Chemistry, 1994

A Texas state senator earned an Ig Nobel for requiring permits to purchase laboratory glassware—one of many times the committee has used its position to spotlight people who hinder science. But just as often, scientists themselves are skewered: In 1993, the literature prize went to all 976 authors of a 10-page biology paper.

Biology, 1999

A spiceless jalapeño might seem like an oxymoron, but a horticulturalist at the Chile Pepper Institute of New Mexico State University was recognized for developing one. The pepper allows a chef to create a salsa that’s mild but still tastes like jalapeños.

Biology, 2004

Two teams won prizes for discovering that herring communicate underwater by emitting gas—that is to say, by farting—at a rate that creates an audible chirp. According to Marc Abrahams, the research diffused an international incident: The Swedish government had initially assumed the chirp was from Russian spy submarines.

Mathematics, 2006

The honour went to a pair of researchers who calculated how many group pictures you must snap for everyone’s eyes to be open in at least one. Their rule of thumb? For groups of 20 or fewer, divide the number of people by three, and take that many photos.

Notable laureates

Theodore Gray

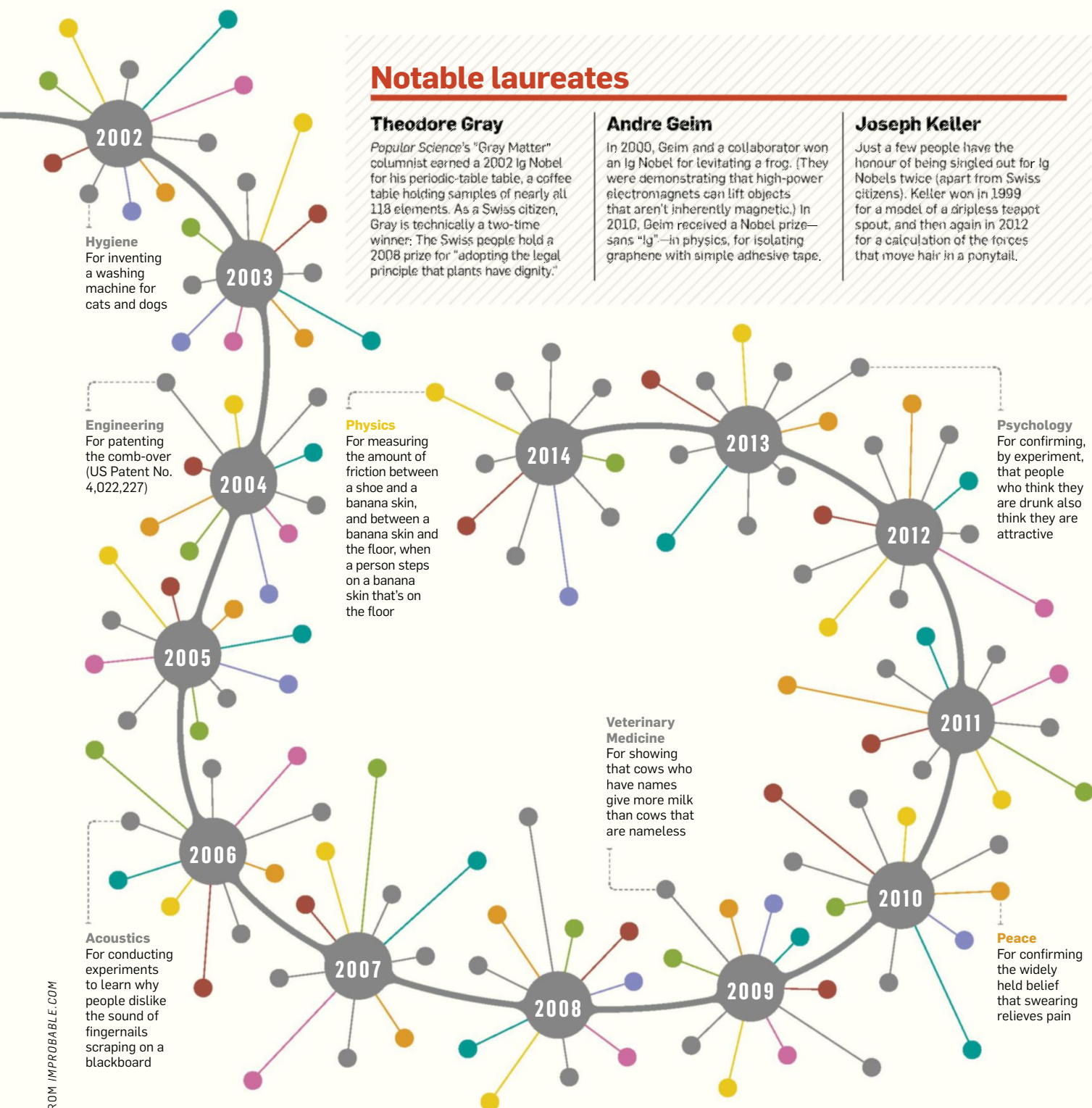
Popular Science's "Gray Matter" columnist earned a 2002 Ig Nobel for his periodic-table table, a coffee table holding samples of nearly all 118 elements. As a Swiss citizen, Gray is technically a two-time winner: The Swiss people hold a 2008 prize for "adopting the legal principle that plants have dignity."

Andre Geim

In 2000, Geim and a collaborator won an Ig Nobel for levitating a frog. (They were demonstrating that high-power electromagnets can lift objects that aren't inherently magnetic.) In 2010, Geim received a Nobel prize—sans "Ig"—in physics, for isolating graphene with simple adhesive tape.

Joseph Keller

Just a few people have the honour of being singled out for Ig Nobels twice (apart from Swiss citizens). Keller won in 1999 for a model of a dripless teapot spout, and then again in 2012 for a calculation of the forces that move hair in a ponytail.



Manual

EDITED BY *Sophie Bushwick*



STATS

Time 2 hours

Cost \$26

Difficulty



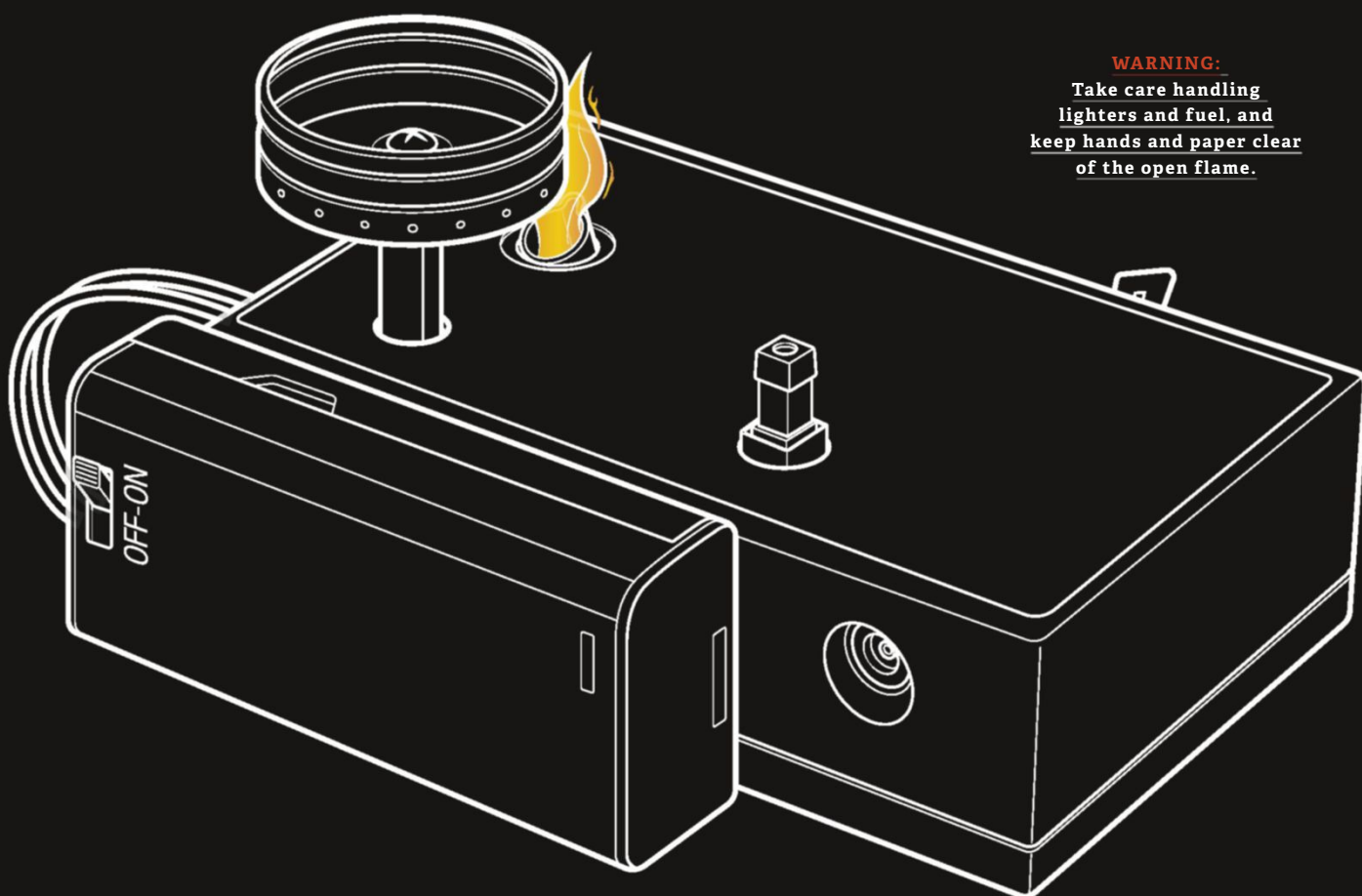
Build Your Own Fairy-Floss Machine



You don't need to wait for the Show to satisfy your craving for fairy floss. Instead, build this portable, pocket-size machine to turn granulated sugar into an airy treat.

A DIY fairy floss machine consists of a small metal container, re-purposed lighter parts to provide heat, and a switch-controlled motor to set everything spinning. Slowly pour granulated sugar into the container, and flames from the lighters will melt it. As the motor spins, the liquid sugar will fly out through little holes in the container's sides, forming thin strands. A paper cylinder placed around the machine will capture them. Once they've built up, simply swirl a chopstick around the perimeter to gather the floss and taste your sweet success.

POCHOLO MANALAC



WARNING:
Take care handling
lighters and fuel, and
keep hands and paper clear
of the open flame.

MATERIALS

- Long-nosed lighter
- Torch lighter
- Wire
- Two-part epoxy
- Superglue
- Metal standoff with a screw, washer, and nuts
- A small cosmetic aluminium container (found in drugstores) or a metal drink cap
- Small project box
- DC motor
- AA-battery holder
- Clay epoxy
- Paper, tape, rubber band, and chopstick

TOOLS



Push pin



Power drill



Soldering iron

INSTRUCTIONS

- To build a system for heating the sugar, first open both lighters. Harvest the large fuel tank, igniter, and hose from the long-nosed lighter and the torch head from the torch lighter.
- Use the long fuel hose to connect the fuel tank to the torch head.
- For an ignition line, wrap a short length of wire around the metal base of the long-nosed lighter's igniter and seal it with epoxy.
- Push the igniter's new wire through the torch head—where the torch lighter's wire previously was. This is the main ignition line.
- Connect the main ignition line to the brass part of the torch head. Seal with superglue.
- Next, set up the spinning chamber. Epoxy the metal standoff to the shaft of the motor. (When joining two parts together with epoxy, sanding both sides will yield a stronger bond.)
- With the push pin, punch holes all the way around the sides of the aluminium container, or drill tiny holes in the metal drink cap. Find the center of the container and drill through it. Add the screws, washers, and bolts to it, and screw it in place on the motor's standoff.
- Solder the battery pack's terminals to the motor. Since the screw tightens clockwise, make the motor spin counterclockwise to prevent it from unscrewing.
- To prepare the project box, plan where you will be placing the fuel valve, igniter, torch head, and spinning chamber. Mark each spot with a marker, and then drill the holes. You may use the pictures as a guide.
- Epoxy the motor in place in the box.
- Glue the battery pack to the outer side of the box. Seal the igniter in place—the end should stick out of the box—with clay epoxy.
- Before sealing the torch system in place with the clay epoxy, measure the torch head and aim it at an angle so the flame will touch the near edge of the metal container.
- To operate the cotton-candy machine, tape paper into a cylinder that fits around it. Then switch on the motor, squeeze the fuel valve (and hold it in position with a rubber band), and spark the igniter. Let the machine heat for 10 seconds, then place the paper cylinder around it and slowly add the sugar. Collect the fairy floss with a chopstick.

HOW 2.0



SEND YOUR DRONE TO GREATER HEIGHTS



There's a universal truth of drone ownership: it's virtually impossible to own a quadcopter for any length of time and not want to stick a bunch of extra features on. The internet is full of DIY ideas, from fireworks (fun) to an actual handgun (a bad idea).

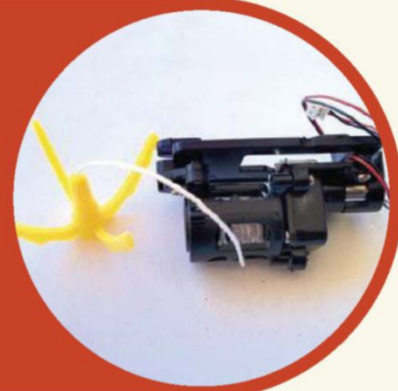
But what about those who don't have the time or DIY skills to turn a quadcopter into something more? Well, there is a range of accessories that add both features and fun to the flying experience. They don't just work with expensive drones either, and are also compatible with the Jaycar GT3810 and GT3820 helicopter range. Installation is as simple as snapping the units into the undercarriage mount and plugging into the controller plugs. **LINDSAY HANDMER**

THE WINCH

Want to perform daring rescues of plastic army men or start a backyard drone delivery service? The winch system can be remotely triggered to raise or lower and comes with a hook and a basket. It can't handle a huge amount of weight, but we did use it to successfully rescue a small RC plane stuck on the roof. The winch itself uses a tiny electric motor, which drives a reel of string through a reduction gearbox. The whole thing only weighs a few grams so doesn't affect the quad's flight time.

Price: \$14.95

Product Code: GT3836



THE WATER CANNON

Mixing H₂O and electronics might sound like a bad idea, but this mini water cannon does it without any fried circuits. The unit has a small tank coupled up to a high pressure pump that feeds water out a squirt gun style nozzle. It manages quite a few good shots, is surprisingly powerful for the size and can hit targets up to three metres away. It uses a peristaltic pump - a type of device that uses a spinning rotor to squeeze water out of a rubber tube. It's quite minimalistic too, so a chosen target won't suspect a thing until hit by a stream of water.

Price: \$14.95

Product Code: GT3834



10

Minutes of flight time from a typical consumer-grade quad copter. Pro models can go for 40+ mins.

**THE JAYCAR QUAD**

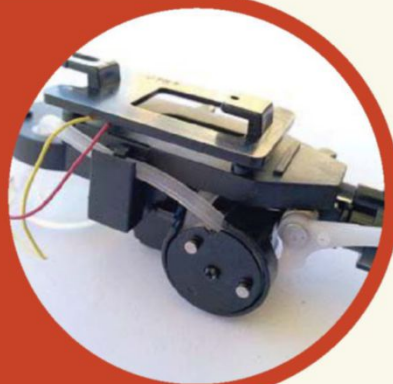
A large, 4-Channel quadcopter, the GT3895 is designed to be easy on beginners, but has enough grunt for more experienced pilots. Importantly it has a six-axis gyro to keep things balanced when learning to fly. The quad also has a bunch of stunt modes, including 360 degree flips. Flight time is up to 10 minutes (but less if pushed hard) and the battery recharges in about an hour. The 2.4GHz remote has a decently long 100m range and plenty of power for outdoor flight. There's also an LCD that gives critical info such as thrust and battery and signal levels. And of course, it has a mounting system for adding extra features.

Price: \$149**Product Code:** GT3895

The more money you spend on a drone, the easier it will be to control, with auto-levelling and auto-land should the battery run down.

THE BUBBLE BLOWER

Want to unleash something a little less potentially electro-destructive than a stream of water? The mini bubble blower add-on can release a flurry of soapy goodness from the sky. It's actually a surprisingly complex little device. A tiny fan pumps air to blow the bubbles, while a pump feeds bubble mixture to the blowing array. It also has a tiny arm that sweeps across, cutting the bubbles free. It even comes with a container of bubble mix and a little squeeze tube to reload the tank. Not surprisingly, watching the bubbles scoot around the in the quadcopter wash, or doing a high speed bubble strafing fun is extremely satisfying.

Price: \$14.95**Product Code:** GT3832**THE CAMERA**

One of the most fun uses for a quadcopter is capturing interesting aerial video. The problem is, most of the available options are expensive or have low resolutions. The Jaycar Quadcopter can hoist a plenty of weight, so an upgrade is easy. The snap on video module records 1080P footage and records it directly to a microSD card. It's got a built in battery too, so does not affect the runtime of the quad. The only downside is that it shares the mounting system with the other drone accessories, so a creative DIY install is needed to capture water cannon surprise attacks.

Price: \$94.95**Product Code:** GT3835

Theme Building

EPIC HOLLYWOOD PROPS, REMIXED

When a new movie hits cinemas, most people grab popcorn. Instead, these DIYers grabbed their toolboxes. Inspired by this year's biggest action films, they built real-life versions of three outrageous props.

LEVI SHARPE



FLAMING UKULELE

In *Mad Max: Fury Road*, the Doof Warrior plays heavy metal on a flamethrowing double-neck

guitar. After watching the movie, Caleb Kraft decided to build his own "adorably dangerous" version of the instrument:

a flamethrowing ukulele. Kraft used a modified caulking gun to squeeze butane into a hose and added an igniter switch. With zip

ties, he attached the whole apparatus to the back of a ukulele, creating a cute, strummable instrument of destruction. "Movies and

videogames are such easy inspiration," Kraft says. "They are the manifestations of what we think would be awesome to exist."

191,271,109

US box-office dollars earned by *Avengers: Age of Ultron* over its opening weekend, the third-highest opening weekend ever

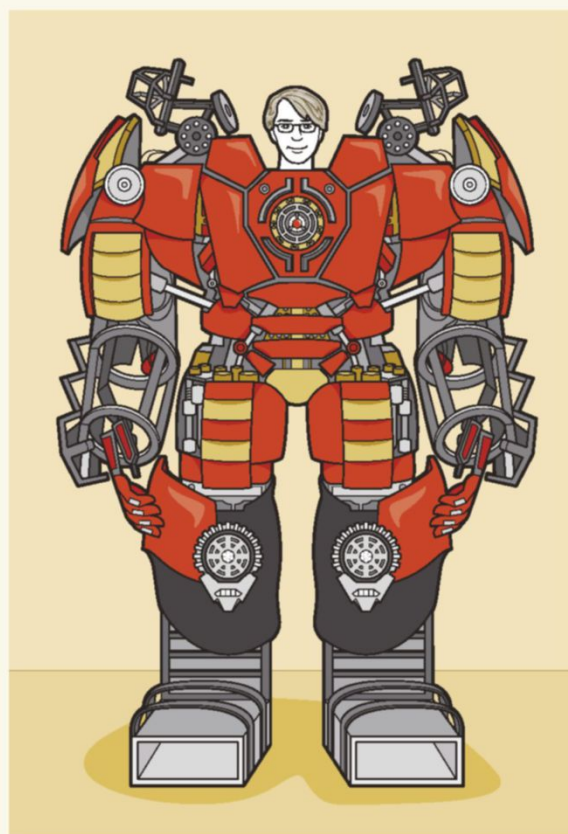


BB-8 DROID

When industrial designer Christian Poulsen saw a BB-8 droid roll onto the stage at an event for *Star Wars: The Force Awakens*, he was struck by the simplicity of the design: a

large sphere with a dome on top. "When I saw that," Poulsen says, "I thought, 'How hard could it be to make my own?'" An app-controlled toy ball called Sphero would make the perfect base, he realised.

First he sawed it open to insert a magnet. Then he carved a head out of foam and embedded a magnet in that too. The magnets hold the head to the body as the toy rolls around, leaning slightly off-kilter.



HULKBUSTER SUIT

In 2014, toy designer James Bruton created a replica Iron Man suit that got him millions of YouTube views. "I thought that if I ever went to a convention, I should have something super-cool to wear," Bruton says. "So I built something that I wanted to own." Now, he's using his YouTube channel to document his work on the superhero's bulkier "Hulkbustor" suit, which appears in *Avengers: Age of Ultron*. Bruton's suit has a plywood frame covered with red foam plates. Bungee cords, snowboard bindings, and 3D-printed parts serve as movable joints. Bruton also outfitted the suit with pop-up shoulder cannons and a glowing chest plate.

This Ballistics Box Measures Fastballs

DIY-history columnist **William Gurstelle** gives ancient warfare a modern spin.



About 300 years ago, English scientist Benjamin Robins decided to measure the speed of a bullet, a task that led him to invent the ballistic pendulum. This device tracks the momentum of a projectile, allowing users to calculate the speed and energy as well. Although the chronograph later replaced that method, the ballistic pendulum has a great advantage: It requires only very simple mathematics.

Basically, the user fires a projectile—in Robins' day, a cannonball or musket shot—at the pendulum. The faster it's moving, the farther the pendulum will swing, pulling measuring tape along behind it. Robins determined that the distance the pendulum swings, along with its weight and that of the projectile, can be used to figure out the projectile's velocity. Bullet speed doesn't interest me, but a ballistic pendulum can measure the speed of any object—including a baseball. With baseball season on, I wanted to build one.

To construct the frame, I used dimensional lumber stiffened with plywood gusset plates. A plastic milk crate lined with crumpled newspaper served as the base of the pendulum. I attached the top of the crate to an aluminium bar, which I then connected to a wooden dowel. The dowel fit through holes at the top of the frame so it could swivel freely like a spit. Finally, I attached measuring tape to the bottom of the crate and ran it through a slot in the middle of the frame. The slot provided just enough friction to keep the tape from sliding back after the pendulum hit peak swing,



**STRAIGHT
DOWN THE
MIDDLE!**

thus recording the measurement. The project took me about half a day and cost less than \$50.

To gauge my fastball, I just pitch the ball into the milk crate. The crate

For drawings and tips on building a ballistic pendulum and calculating a projectile's velocity, hit up Google for many many plans.

swings up, and the tape registers the distance of the pendulum's arc. Using Robins' original equations, I can calculate my pitch speed. It's way more satisfying than using a radar gun.

FLYING FOX DESIGNER

Thaddeus Shrader used to cruise the skies as an airline captain. But in 2008, he switched to a career creating new ways to soar: flying foxes. He's now the CEO for Bonsai Design, which specialises in building flying-fox courses that minimise the damage to forests. "You're flying in and out of living structures," Shrader says. "We have to figure out a way to make the whole thing safe and legal."

DAVE GERSHGORN

How did you go from flying planes to designing flying-fox components?

I went to college for aeronautical engineering. At that time, there wasn't a lot of work for aeronautical engineers, so I got a job as a pilot. After my wife and her brother started running this company, I came over and brought my engineering background. That's when Bonsai really started inventing new components: new trolleys, harnesses, braking systems, and emergency-rescue devices.

What's the appeal of flying-foxes?

This is the closest you can get to the real



feeling of flight. The wind is in your hair, you're above the ground, your wings-slashed arms are out from your side, and you're blasting along. It's beautiful.

Do you get to play with your designs?

A Bonsai Design challenge course 60 feet up in the trees, located in Mount Hermon, California.

We're always trying to figure out new ways for people to fly, and we have to test all those ideas. My kids are our test monkeys. We actually develop a lot of stuff in our backyard—and we get paid to do it.

Turn a Rainy Day into Art

Seattle artist Peregrine Church uses rain as his medium. By stencilling images and words on the footpath in water-repellent spray, he creates Rainworks—art pieces that appear only when it's wet outside. Instead of shelling out \$45 for the paint Church uses, you can follow the lead of DIYer Dan Rojas to make your own. Rojas discovered that spray antiperspirant contains a commonly used hydrophobic chemical. Clear spray paint binds it in place, creating a cheap water repellent that can last for months. "A lot of the stuff you see," Rojas says, "was made when people put two or three products together and came up with something new." **REBECCA HARRINGTON**



WATER WORKS

STATS

Time 1.5 hours

Cost \$15

Difficulty

• • • • •

MATERIALS

- Cardstock
- Clear spray paint
- Aerosol antiperspirant

INSTRUCTIONS

- 1 Cut a stencil out of cardstock and place it on the footpath. Spray with clear paint.
- 2 While the clear coat is still wet, mist with deodorant.
- 3 Remove the stencil and let the paint dry for about an hour.
- 4 Wait for rain to reveal your art—or maybe just use a garden hose.

IS THERE ANYBODY OUT THERE?



In October 1984, *Popular Science* wrote about one of the more promising chapters in the search for intelligent life. NASA was set to embark on a 15-year mission: An 25-m-tall radio telescope would filter out the torrent of chaotic radio signals it received while it scanned the universe, "seeking the one unambiguous pattern that would signify something totally extraordinary," we wrote. Sadly, those efforts didn't yield much, and today NASA is focused on finding any life—intelligent or no. In the decade to come, the agency plans to send a spacecraft to Jupiter's moon Europa, which could possibly harbour life beneath its icy surface. To learn more, turn to page 36.

LEVI SHARPE

06

Number of users, in millions, who have participated in SETI@Home, which allows people to monitor for alien radio signals with their personal computers.



HOW TO SPOT AN ALIEN

GAMMA-RAY BURSTS

In 1995, a scientist at MIT Haystack Observatory proposed that extraterrestrials might communicate with gamma rays. Since then, the Fermi Gamma-ray Space Telescope has been on the lookout.

TECHNOSIGNATURES

Since 2005, Fermilab in Illinois has been surveying the universe for city lights, atmospheric contamination, or any other infrared sources that could indicate the use of advanced technology.

OPTICAL EXPERIMENTS

A Harvard-Smithsonian group is building a 1.8-metre aperture telescope to detect powerful lasers, in case extraterrestrials use them to communicate.

BIOSIGNATURES

The new James Webb Space Telescope, set to launch in 2018, will search for exoplanets, but also for signs of life—oxygen and methane—in their atmospheres.

Go Ahead...

Ask Us Anything

ANSWERS BY **Daniel Engber**
ILLUSTRATIONS BY **Jason Schneider**

Have a burning question?
Email it to [letters](mailto:letters@popsci.com.au)
@popsci.com.au or tweet it
to @popsciau #AskAnything.



Q: Will practicing a skill in your head make you better at it?

Short answer Only if you're already good.

A:

When Carson Palmer, the two-time Pro Bowl quarterback for the Arizona Cardinals, hurt his elbow a few years ago, he took a week off from throwing the football. But in his head, Palmer practiced every day. "You stand right behind the centre, and you see the coverage unfold as you would if you had the ball in your hands," he told ESPN. It seemed to do the job. The following weekend, Palmer had the best game of his career.

For more than a century, scientists have been trying to understand how this mental training works. In the 1930s, researchers demonstrated that when you're imagining an action, your brain sends signals to your muscles—subtle triggers

too weak to make the muscles contract but ones that might help train the body to perform. Alternatively, mental practice might create a blueprint in your head, like an inner how-to guide for a particular skill.

Sports psychologists have conducted hundreds of studies comparing imagined and physical practice for actions such as throwing darts, juggling, and tap dancing. Overall, the research shows that mental training works. A 2012 study, for example, compared 32 amateur golfers who putted to another 32 who merely held a golf club in their hands and visualised their swings. Under the same training regimen, both groups improved their putts by getting the ball about 10 cm closer to the hole.

Visualisation has advantages over the real thing: You can do it anywhere, even when injured. It's safe—a major plus for high-stakes performers such as gymnasts and surgeons. And you can practice for longer periods of time because you're not constrained by physical fatigue. That's not to say it's easy: "We've had Olympic-level athletes sitting in our lab, visualising for two hours," says Tadhg MacIntyre, a sports psychologist at the University of Limerick in Ireland. "When we're done, they're absolutely exhausted."

It doesn't work for everyone, though. "If you're a novice, the impact can be negative," warns MacIntyre. "If you're trying to visualise a free throw, and you don't even know the proper handgrip and movement, then you're probably going to mentally rehearse the wrong skill, and your skill is going to be impaired."



Q: DO THOSE GUYS WITH METAL DETECTORS EVER FIND TREASURE?

Short answer Every once in a (very long) while.

A:

In 1975, a metal-detector hobbyist named Morton Leventhal made the front page of *The New York Times* when he stumbled on a piece of Roman antiquity. The Wall Street stockbroker was scouring a field overlooking the Jordan River in Israel when his Metrotech device started bleeping. He pulled out his knife and scraped away the dirt to reveal a life-size bronze statue of the Roman Emperor Hadrian, from the second century—a piece so rare it's now in the Israel Museum in Jerusalem.

Finds like that fuelled the metal-detecting craze of the late-1970s and 1980s. "Detectorists" of that era benefited from a major technology

upgrade: the Very Low Frequency detector, which offered better ground-penetration than earlier models. In fact, hobbyists became so adept at finding buried treasures that professional archaeologists recruited them to scour Civil War battlefields and other historic sites, which they still do today.

But their prowess might be a bit overblown. Amateurs do, on rare occasions, turn up valuables: an Iron Age cache of Celtic coins in June 2012, another collection of Roman coins a few months later. But that doesn't mean it's a good way to prepare for retirement. A 1990s British survey of the hobbyists found that hardcore detectorists reported a median 13 finds per year.

"It's incredibly unlikely to find an item that is worth millions of dollars," says Suzie Thomas, a museologist at the University of Helsinki. She adds that most detectorists are simply in it for the hunt. "If you're in it to get rich, you'll probably give up after a few months."

Q: Can hypnosis kill you?

Short answer No, but you're getting veeeeeeery sleepy.

A:

The first account linking hypnosis and death in the medical literature was in 1894. Ella Salamon, niece of a Hungarian count, was put into a trance and then "fell from her chair with a hoarse cry," according to an attending doctor. "There is no doubt that she died in hypnosis," said Richard von Krafft-Ebing, a noted psychiatrist of the time, "but that she died by hypnosis is questionable."

Accounts of such fatalities or psychiatric harm from hypnosis have appeared sporadically ever since. In 1979, a stage hypnotist asked a young Israeli mother to regress to childhood—a time when she'd been hiding from the Nazis. She later reported that the newly uncovered memories put her in a state of distress for years. Other reports tell of trance subjects left stuporous and suicidal.

But these cases are anecdotal. Studies suggest that the negative side effects are generally mild at worst. In the 1970s, researchers from California State University in Fresno looked into the risks by hypnotising 209 undergraduates. A few suffered headaches or nausea; 25 reported feeling light-headed or drowsy—hardly worse than what the students experienced taking an exam or sitting through a lecture.

"Hypnosis, in and of itself, isn't dangerous," says psychologist Bruce N. Eimer. It can be a therapeutic tool; but like all tools, he says, in the hands of someone incompetent or who uses it inappropriately, it can cause harm. "Would a massage therapist perform acupuncture on an 84-year-old with osteoporosis?" Eimer asks. Probably not. Similarly, it would be unwise for a clinician to use hypnosis without first assessing if a patient is too psychologically fragile. ☹️



Retro Invention



THE INTERNAL COMBUSTION ANALOGUE

The simplest jet possible, the valveless pulse jet works using some of the same principles as the putt putt engine. Unlike a typical jet which continuously burns fuel, the pulse jet instead creates thrust through a series of discrete explosions. A valveless pulse jet has no moving parts and can operate with almost zero maintenance. In operation, fuel and air is exploded in the engine, and focused out two different length tubes, creating a burst of thrust. The cooling low pressure gas draws fresh air into the engine through the shorter tube, which is mixed with fuel and exploded again, continuing the cycle. Valveless pulse jets have been used to power all sorts of things, from cruise missiles to go-karts.

The Putt Putt Boat

An ingenious toy that uses a unique form of propulsion



Kids today can pick up a toy helicopter with three-axis radio control for about \$30. But for the preceding 150 years, they had to get their miniature vehicle kicks in a simpler, though really no less ingenious, way. Such as via this, the putt putt boat. Or pop pop boat. Or can can boat. Or poof poof, phut-phut and Pouet-Pouet. Whatever the name, the concept remains the same.

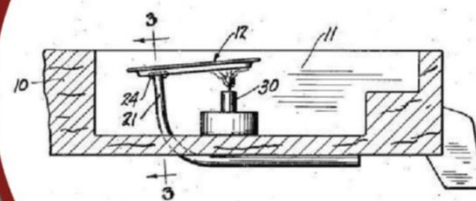
At the core of every putt putt boat is a simple heat engine that

heats water into steam, which then provides thrust. The engine consists of a boiler tank, connected to an exhaust tube. Heat is applied to the boiler (usually from a candle or small oil reservoir), and as the water evaporates, it expands. The expanded steam pushes the water in the exhaust tube out, creating thrust. Now cooled, the bubble of steam in the boiler condenses, creating a vacuum and drawing water back into the exhaust tube and boiler. Once again this water is heated, turns to steam and the cycle continues.

Since the boiler made from a thin sheet of metal, the expansion and contraction cycle causes it to flex, creating the putt-putt noise that gives the toy its name. Boilers can be a variety of shapes, with single or double exhaust tubes. The simplest putt putt engines use a coil of copper tubing as the boiler, with both ends of the pipe acting as exhausts.



You can dedicate hours to painstakingly recreate the Lusitania, buy a pre-built tin Titanic on eBay... or just carve up a Coca-Cola can for instant putt-putt gratification. No mother, it's not a bong...



HOW IT WORKS

When you think about it, the propulsion of the putt putt boat is a little counter-intuitive. Since the engine both forces water out and then sucks it back in, it would be natural to expect the boat to just shake back and forwards without a net forward motion. But the operation is actually more complex. When the water shoots out of the engine, the boat is propelled forward. When the engine sucks the water in, it does accelerate backwards. But when the moving water comes to a stop inside the boiler, it imparts its forward motion onto the boat. The backwards motion is totally cancelled out, leaving a net forward velocity.

Credit for the putt putt boat is given by most historians to a Frenchman named Thomas Pict in the late 1800s

- certainly, in 1891 he filed for a patent on the invention. In the early 1900s, Charles J. McHugh made numerous improvements to the design.

In 1920, William Purcell invented the coiled tube style putt putt engine. Throughout the 40s and 50s the putt putt boat was a very popular toy and could be bought commercially, though it was also a classic home project for enterprising kids to build by hand out of bits and pieces lying around. Mostly by boys because in those days gender roles were harshly enforced with corporal punishment.

Like all classic toys, putt putt boats eventually lost out to newfangled multi-function electronics and especially remote control.

WHY ONLY TOYS?

So why hasn't the putt putt engine

been used to power full size boats? For a start, they are very inefficient at turning heat into motion, compared to an internal combustion engine and propeller. They also don't throttle up and down easily and have no reverse gear. As a powerplant, this technology doesn't scale up very well - bigger engines have a lower power to weight ratio. The bigger exhaust pipes also mean a lower water velocity, and less thrust. If you want to give it a try anyway, here's a tip: multiple smaller engines work better than a single large version.

Still, this little steamboat is having a bit of a resurgence in more recent times, and was featured in the animated film *Ponyo*. We advocate building a putt putt with your kids. Hit up Google for an almost overwhelming selection of plans and instructions - from simple tin toys to scale models of famous ships.

Some enthusiasts collect rare putt putt boats, while others build complex versions to try and make them faster or more powerful. Daryl Foster (check out his Youtube videos) has built hundreds of engine designs, including ones with seven or more exhaust tubes!

LINDSAY HANDMER

Labrats

STORY BY **Subject Zero**



BODYWELL LIFE COACH IMPLANT

Further inspiration from
the ghost in the shell



Time is a spiral. I know this because once again I'm explaining to my agent the bonesaw thing. Namely, that as an itinerate scientific test subject, I will do anything for \$125 that doesn't involve bonesaws. My new agent, ex-union man Kurt Blockade doesn't seem to get it.

"Come on man," he says, holding out the indemnity form. "You let that monkey bite your hand off."

"I didn't LET him bite my hand off!" I shriek, batting the form away with my reattached hand. The scar is like a livid purple bracelet. "And anyway, he wasn't a monkey. He was an ape."

Kurt Blockade rolls his eyes up toward his massive eyebrow, and then back down again to the indemnity form. "But mate, it's a TRIPLE. All you need to do is let them implant the Bodywell prototype and leave it in there for 24 hours. Just to see if, you know, your body violently rejects it. Come on -" He draws breath to unleash a "Maaaaate" which is my very least favourite of all his many remaining unionisms, so I say "Okay okay!"

The young man in the medical suite with us beams, and hefts the bonesaw. He steps forward. "Wait" I interrupt him. He makes an irritated humphing sound. "All I'm saying is that if you DO have to use the bonesaw, does it HAVE to go in the back of my head? I mean, why not an arm? I can spare an arm." I look at the purple scar around my wrist again. "More or less."

The young man in the white coat shakes his head. "Nope, has to be the skull. Bodywell needs a low voltage interface with the living brain."

"You did say LOW voltage?"

"Yes. Now relax. It won't hurt a bit." As usual, this is a total lie.

Some hours later I regain consciousness in my ratty apartment to see Aristides, my cat, looking at my left ear and licking his lips.

"Not this time," I say, pushing him off the couch. A bolt of electric pain hits me from behind, sending me crashing to the floor.

"INEFFICIENT USE OF TIME!" booms a disembodied robot voice from somewhere behind me. "CATS CANNOT PROCESS ALLUSIVE LANGUAGE."

"What the frunk?" I moan, reaching up to feel the back of my head. Another shock sends me reeling.

"DO NOT INTERFERE WITH THE IMPLANT. BODYWELL ASSISTS YOU IN LIVING LIFE TO THE FULLEST. PAIN AVERSION THERAPY WILL PREVENT FURTHER WASTE OF TIME."

Further waste of time? I think. I stand up, gingerly, go to the wheezing fridge, gingerly, and reach past some old ginger for a beer. My fingers barely close around the neck of a stubbie before another bolt of pain knocks me flat.

"CONSUMPTION OF ALOCOHOL IS NOT PRODUCTIVE USE OF TIME," booms the implant.

"Argh!" I say. "Well you stupid thing, what do you SUGGEST I do with my time?"

"BODYWELL DOES NOT IMPINGE ON FREEDOM OF CHOICE. USER FREEDOM OF CHOICE IS PARAMOUNT."

I feel my eyes starting to roll around a bit, either from terror or maybe the repeated shocks. I ask myself the question I've asked so many, many times before: why

didn't I read the small print on that indemnity form?

The rest of the afternoon I

spend trying to get myself back to Bodywell's offices on the outskirts of the city. The implant won't let me take a cab, or a bus. I'm staggering along the street, sweat pouring from my brow and staining the bandage that's still wrapped around my head. I imagine there's a bloodstain on the back - people avoid me even more than usual. Or maybe it's because I'm dragging Aristides on a leash and he's yowling like... like a cat being dragged along on a leash. "Because we're in this together!" I yowl back at him.

Eventually I make it, hurl myself through the double doors into the air-conditioned lobby of Bodywell, and scream: "GET THIS THING OFF ME!"

The pretty receptionist studies my sweat-and-blood-soaked form for a moment.

"I think he'll run off if you just let go of the leash," she says.

I look down. Aristides has decided to deal with his "walk" by clinging onto my leg with four sets of claws.

"Not the cat!" I yell. "The implant! This thing in my HEAD!"

The young man from earlier wanders into the lobby holding some kind of medical-grade iPad.

"Oh there you are!" he says. "Ready for me to activate the implant yet?"

There's a long pause, broken only by my shrieking as Aristides starts climbing further up my leg.

"FOR FUTURE REFERENCE," says the thing in my head which turns out not to have been the Bodywell implant at all. "THE EXPIRED PASTRAMI IN YOUR FRIDGE WAS NOT OKAY TO EAT. WE ARE THE MICROBIAL GESTALT, AND WE SHALL BE WITH YOU ALWAYS."

We'll see about that, I think, feeling the back of my head. I sneer, then point at the young man with the iPad. "You," I say. "Get the bonesaw."



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October 2015
On sale 24th
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